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معاك
Ma3ak App

Interactive E-learning Application

MAIN BOOK

FIRST TERM

Contents

UNIT

1

Chemistry is the Central Science

Chapter One Chemistry and Measurement.

Chapter Two Chemistry and Nanotechnology.

Exam model on the unit

Learning outcomes of unit one

By the end of this unit, the student will be able to :

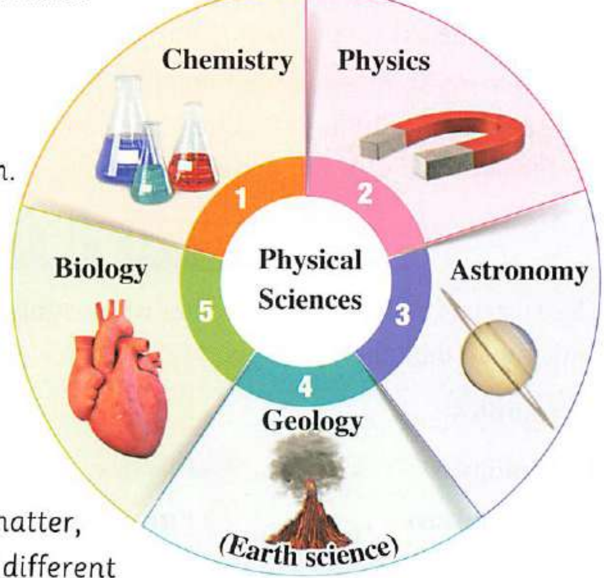
- Identify what is chemistry.
- Explain the relationship between chemistry and the other branches of science.
- Identify the nature of measurement and its importance.
- Mention the tools and apparatuses used in chemistry labs.
- Use practical tools which are suitable for the curriculum with accuracy and efficiency.
- Understand the concept of Nanotechnology.
- Specify some of the applications of the chemistry of Nanotechnology.
- Conclude that some of the applications of Nanotechnology have useful effects, while others are harmful.

The included life topic : Science, technology and the society.

Chapter **One**

Chemistry and Measurement

Since the beginning of mankind, he is searching and exploring the surrounding universe to **understand** its phenomena, **explain** it and even to **control** it. All of what man had reached from his researches is coordinated in a structure called **Science** which is an organized structure of knowledge that includes facts, concepts, principles, laws, scientific theories and an organized method in research and investigation.



- **The field of science differs according to :**
  - The different phenomena under study.
  - The used methods in research.
  - The used tools.
- **Chemistry** is one of **the natural sciences**.

Chemistry is the science that is interested in studying the composition and properties of matter, the changes that occur to it, the reactions of different substances with each other and the suitable conditions for these reactions.

Importance of chemistry in ancient civilizations

- The ancient Egyptians used some chemicals in mummification.
- **Since the ancient civilizations, chemistry has been related to :**
  - Metals and mining.
  - Medicine and medicaments.
  - Some technical industries, **such as :**
    - Tanning.
    - Dyeing of clothes.
    - Glass industry.
    - Colors industry.
  - Nowadays, chemistry has very essential roles in all aspects of life.

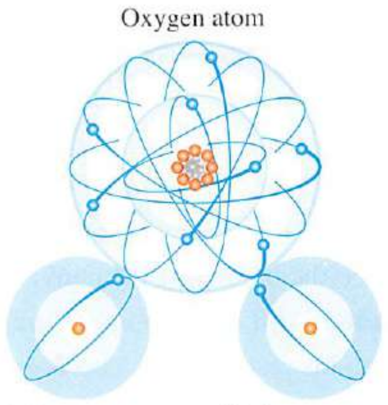
Chemistry has been divided into branches like :

1. Physical chemistry.
2. Biochemistry.
3. Organic chemistry.
4. Analytical chemistry.
5. Thermochemistry.
6. Nuclear chemistry.
7. Electrochemistry.
8. Environmental chemistry ... **and other else.**

The fields of chemistry studies

The science of chemistry is interested in :

1. **Studying** the atomic and molecular structure of matter (the bonds within it) to identify the properties of the different substances qualitatively and quantitatively.
2. **Understanding** and **controlling** the chemical reactions and their conditions.
3. **Obtaining** new beneficial products that can be used in medicine, agriculture, engineering and industry.
4. **Treating** some environmental problems, **such as :** Pollution of (water - air - soil), the shortage of water and energy crisis.



Molecular structure of water molecule

Chemistry is the central science

Chemistry is considered the center of most of other sciences, because it is essential to understand the other sciences.

Examples

1. **Biology.**
2. **Physics.**
3. **Medicine and pharmacy.**
4. **Agriculture.**
5. **Future sciences.**

1 Chemistry and Biology

Biology is interested in studying the living organisms.

- Chemistry is interested in studying the chemical reactions that occur inside the living organisms (**e.g.** digestion, respiration and photosynthesis).
- Chemistry is combined with biology in a science called Biochemistry which is interested in studying the chemical composition of the components of the cell in various organisms (**e.g.** carbohydrates, fats, proteins and nucleic acids).

Chemistry contributes in identifying the components of the human body

2 Chemistry and Physics

The magnetic properties of the iron filings

- **Physics is interested in :**
  - Studying all about the properties of matter like its movement, energy, mass and velocity.
  - Inventing new more accurate methods for measurement.
  - Trying to understand the natural phenomena and the forces affecting them.

- Chemistry is combined with physics in a science called **Physical chemistry** which is interested in studying the properties and the structure of matter as well as the particles that form this matter.

3 Chemistry, Medicine and Pharmacy

Medicines are chemical compounds that have therapeutic properties and can be extracted from natural sources or prepared in laboratories.

Some cough medicines are extracted from Guava leaves

- Chemistry plays an important role in each of medicine and pharmacy fields, by knowing the nature and the functions of the hormones and the enzymes, and explaining the role of medicine in treating the hormonal and enzymatic disorders.

4 Chemistry and Agriculture

Chemistry helps in agriculture through :

- Selecting the suitable soil for planting a certain crop through **the chemical analysis** which determines the proportions of the soil components and their sufficiency for this plant or crop.
- Increasing the productivity of crops, as chemistry can prepare **the suitable fertilizers** for each crop.

Fertilizers increase the fertility of the soil

- **Producing the insecticides** to get rid of the agricultural pests.

5 Chemistry and the Future

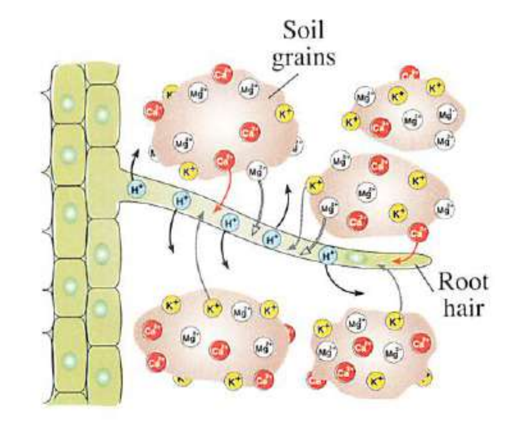
We can **discover** and **form** some substances with extraordinary properties through using Nanochemistry which is the science that is interested in discovering and forming new substances with extraordinary properties that may be used for improving various fields to provide numerous human needs.

* As we will study in the next chapter, these substances may be used for improving various fields like engineering, communications, medicine, environment, transportation and provide numerous human needs.

Worked Example

The opposite figure represents the movement of the ions with and against the gravity of earth through a root hair of a plant,

this represents a certain kind of integration of chemistry, ...



(a) medicine and agriculture.

(b) biology and medicine.

(c) physics and biology.

(d) agriculture and physics.

Idea of answering :

∵ The movement of the ions through a root hair of a plant includes the integration of chemistry and biology.

∴ The choices (a) and (d) are excluded.

∵ Physics is the science which studies the forces such as the gravity.

∴ The figure illustrates the integration of chemistry, physics and biology.

Answer : The correct choice is (c)

Measurement in Chemistry

* The advancement of the scientific, industrial, technological and economical fields is the result of the correct and accurate use of **Measurement principles**.

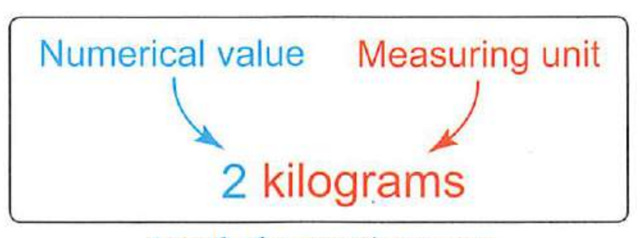
Measurement is the comparison of an unknown quantity with another known quantity of the same kind in order to know the number of times which the unknown includes the known quantity.

Mass of one pin 0.5 g	
Mass of unknown number of pins 90 g	
Number of pins = $\frac{90}{0.5}$ = **180 pins**	

The concept of measurement

Any measuring process must include two main points, which are :

1. **Numerical value :** Describes the measured quantity or property.
2. **Suitable measuring unit :** Indicates a certain standard to which the measured quantity is being referred (in the international measurement system SI), and it is defined as *a certain portion (definite magnitude) of a certain physical amount (quantity) used as an indicator to measure an actual portion of this amount (quantity).*



A result of a measuring process

Test Yourself

Which of the following expresses a quantitative measurement ?

(a) Aluminum bar is longer than copper bar.

(b) The first solution is more concentrated than the second solution.

(c) The colour of the first solution is blue.

(d) The temperature of the second solution is 60°C

Idea of answering :

Any quantitative measurement includes a numerical value and a measuring unit.

Answer : The correct choice is ....

The importance of measurement in chemistry

* Measurement provides us with the necessary information and quantitative data to help us take the proper decisions and the required measures in the different aspects of life, **such as :**

- Environment.
- Nutrition.
- Health.
- Agriculture.
- Industry.

The importance of measurement is manifested in :

1. Giving information about the type and the concentration of the elements forming the substances.
2. Monitoring and health protection.
3. Diagnosis and suggesting the suitable therapy in case of defects (diseases).

1 Giving information about the type and the concentration of the elements forming the substances

* Nutrition facts labels are very important for the consumer, as they enable him to be aware of the types and the concentrations of the components.

Application

Measuring the concentrations of the ions which form the salts in mineral water.

* **By analyzing the data on the labels of each of the two bottles, the following can be concluded :**

- It is much better for the person who follows low salt diet to use bottle (A), where it contains lower amounts of ions forming the salts.
- The person who consumes 1.5 L of water of bottle (B) during one day will receive an amount of calcium ions Ca^{2+} equals $70 \times 1.5 = 105$ mg

Components	Concentration in bottle (A) (mg/L)	Concentration in bottle (B) (mg/L)
Na^+	25.5	120
K^+	2.8	8
Mg^{2+}	8.7	40
Ca^{2+}	12	70
Cl^-	14.2	220
HCO_3^-	103.7	335
SO_4^{2-}	41.7	20

2 Monitoring and health protection

Health protection requires monitoring the validity of water for human use

* Environmental safety and health protection both require monitoring **each of the following :**
  - The validity of drinking water for human use.
  - The purity of air.
  - Safety of food and agricultural products.

Application

Monitoring the validity of drinking water for human use according to international standards.

* The table shows the international standards to evaluate the validity of drinking water, and according to these standards, the bottles (A) and (B) are both valid for human use, as the concentrations of the ions in both of them are within the safety range.

The international standards of the concentrations of the ions in water (mg/L)	Concentration in bottle (A) (mg/L)	Concentration in bottle (B) (mg/L)
$Na^+ < 150$	25.5	120
$K^+ < 12$	2.8	8
$Mg^{2+} < 50$	8.7	40
$Ca^{2+} < 300$	12	70
Cl^- (200 : 250)	214	220
$SO_4^{2-} < 250$	41.7	20

3 Diagnosis and suggesting the suitable therapy for diseases

- Medical analyses reports indicate the health status of the patients by comparing their medical analysis values with the values of healthy persons which are known as **The reference value** which is the normal range of the lowest and the highest values obtained from normal healthy people.

Application

* **Using the opposite medical analysis report to clarify the following :**
  - The amount of **glucose** in this person's blood is within normal range.
  - The level of **uric acid** is abnormal, it is higher than the normal reference value range.

Type of analysis	Value of analysis (mg/dL)	Reference value (mg/dL)
Glucose	70	70 – 110
Uric acid	9.2	3.6 – 8.3

- This indicates the presence of a certain malfunction in this person's body that needs to be treated.

Test Yourself

The opposite table illustrates the results of the analyses of a person before eating breakfast. These analyses indicate that this person suffers from the elevation of ....

Analysis	Result	Reference value
	g/L	
Blood glucose	1.09	0.7 : 1.1
Uric acid	0.06	0.035 : 0.07
Cholesterol	2.5	1.2 : 2
Triglycerides	1.82	0.35 : 1.57

(a) blood glucose and uric acid.

(b) uric acid and cholesterol.

(c) cholesterol and triglycerides.

(d) blood glucose and cholesterol.

Idea of answering :

∵ The amount of blood glucose ....

∴ The choices .... and .... are excluded.

∵ The level of uric acid is ....

∴ The choice .... is excluded.

Answer : The correct choice is (c)

Measuring tools in the chemistry laboratory

- Chemical experiments are performed in the chemistry laboratory, because they require :
  - Safety precautions.
  - A source of water.
  - A source of heat (e.g. **Bunsen flame**).
  - Cupboards and shelves to store chemicals, tools and various apparatuses, among them are :

Chemistry laboratory

1. **The sensitive balance.**
2. **Beakers.**
3. **Graduated cylinders.**
4. **Flasks.**
5. **Burette.**
6. **Pipette.**
7. **Tools of measuring the pH value.**

- It is necessary to know how you can use each of these tools and apparatuses.

In the following we will discuss some of these tools and apparatuses.

1 The sensitive balance

- **Digital balances** are the most common.
- **The top loading balance** is the most commonly used digital balance.
- Before using the balance, you have to read the instructions which are present on one of its sides.

Top loading digital balance

Usage

- It is used to measure **the masses** of substances accurately.

2 Beakers

Transparent beakers are made of **pyrex glass** (heat resistant).
Some beakers have definite capacity, some of them are graduated (beginning from the bottom to the top).

Graduated beakers

Usage

- Mixing the liquids and solutions.
- Transferring a known volume of liquid.

3 Graduated cylinders

Graduated cylinders are made of **glass** or **plastic**.
There are cylinders with different capacities, and they are usually graduated (beginning from the bottom to the top).

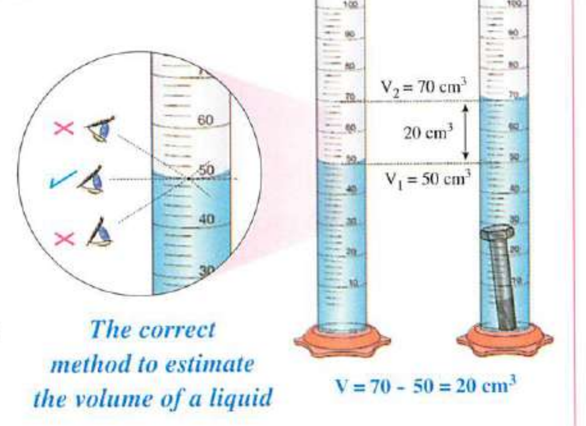
Graduated cylinders with different capacities

Usage

- Measuring the volumes of **liquids** where they are **more accurate** than flasks.
- Determining the volume of a solid body which doesn't dissolve in water.

Check your understanding

How can you determine the volume of a solid body which does not dissolve in water by a graduated cylinder ?



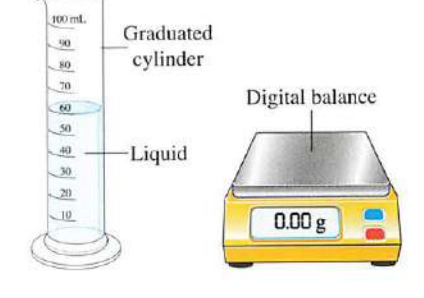
The correct method to estimate the volume of a liquid

- A suitable amount of water is placed in the cylinder and its volume is determined V_1
- The solid body is placed in that amount of water carefully inside the cylinder and the resulting volume is determined V_2
- The volume of the body V = the difference between the resulting volume and the volume of water alone.

$\therefore V = V_2 - V_1$

Worked Example

One of the students used the graduated cylinder which is shown in the opposite figure to measure a certain volume of a liquid, then he determined the mass of the graduated cylinder containing the liquid by using the digital balance. What should be measured to determine the density of this liquid ?



(a) The height of the liquid in the cylinder.

(b) The mass of the empty cylinder.

(c) The temperature of the liquid in the cylinder.

(d) The volume of the empty cylinder.

Idea of answering :

To determine the density of any liquid, it is required to know the mass of a certain volume of it.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

∵ The volume of the liquid is determined by the graduated cylinder.

∴ It is required to determine the mass of this volume of the liquid.

∵ Mass of the liquid in the cylinder =

Mass of the cylinder containing the liquid – Mass of the empty cylinder

∵ Mass of the cylinder containing the liquid is determined by using the digital balance.

∴ It is required to determine the mass of the empty cylinder.

Answer : The correct choice is (b)

4 Flasks

- Flasks are made of **pyrex glass**, because it resists heat, so they do not break with heating or by the effect of the heat of the chemical reactions.
- Flasks have many different capacities.

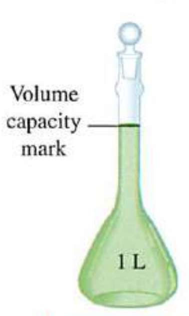
There are various types of flasks, according to their function and capacity like :

Conical flask

- It has a flat base.
- It is used in titration.

Round-bottom flask

- It has a rounded base.
- It is used in the chemical preparations and distillation.



Volumetric flask

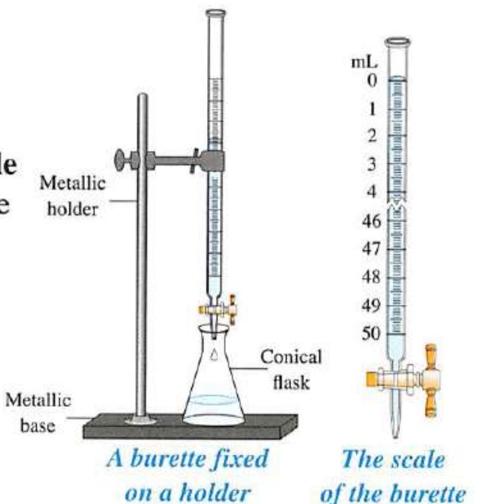
- There is a mark on its neck to determine the volumetric capacity.
- It is used to prepare solutions with very accurate known concentrations (the standard solutions).

5 Burette

- The burette is a long glass tube with two openings, the upper one is used in filling the burette with a solution and the other lower opening has **a fixed valve** to control the amount of solution dropped from it.
- In the burette, **the zero mark on the graduation scale** is close to the upper opening and the scale ends before the valve (**i.e.** its scale is from its top to its bottom).

Usage

- It is used to measure volumes of the solutions with a high degree of accuracy during **titration**.
- The burette is fixed on a holder with a metallic base to preserve its vertical shape during the experiments.



A burette fixed on a holder

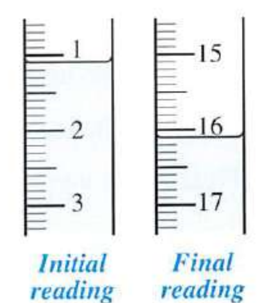
The scale of the burette

For illustration

Titration process is a neutralization process between an acidic solution and a basic solution to identify the concentration of the solution **(with known volume)** in the conical flask by knowing the volume and the concentration of the solution which is used in the burette.

Worked Example

The opposite figures represent two sections in one measuring tool :
Which of the following represents both the name of this tool, and the volume of the transferred liquid ?



Initial reading *Final reading*

Choices	Tool	The volume of the liquid
ⓐ	Burette	16.1 mL
ⓑ	Graduated cylinder	16.1 mL
ⓒ	Burette	15 mL
ⓓ	Graduated cylinder	15 mL

Idea of answering :

∵ The graduation scale of this tool begins from the top to the bottom.

∴ This tool is a burette.

∴ The choices ⓑ and ⓓ are excluded.

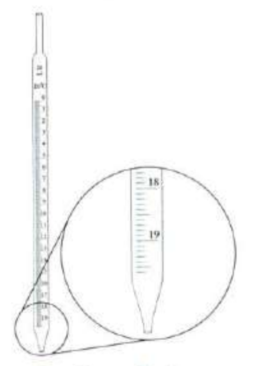
∵ The volume of the liquid = Final reading – Initial reading

∴ The liquid volume = 16.1 – 1.1 = 15 mL

Answer : The correct choice is ⓒ

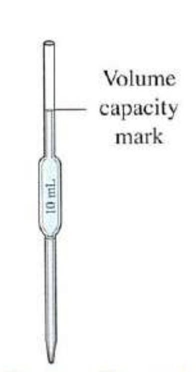
6 Pipette

- It is a long glass tube opened from the two sides, recorded on it **the volume capacity** and **the error percentage** (some of the pipettes have one bulb and some have two bulbs and the latter are the most common in laboratories) .
- They are either graduated or of a predetermined capacity.



Graduated pipette

Pipette with a sucking tool



Pipette with one bulb

Usage

- It is used to accurately **measure** and **transfer** a certain volume of solution.

★ **How to be used :**

- Some of them are filled by mouth sucking and this **must be with extreme caution**.
- The others are supported with a sucking tool, because these are used with very hazardous materials (more preferred to be used).

7 Tools of measuring the pH value (hydrogen ion exponent)

pH value

A value which refers to the concentration of hydrogen ions H^+ in the aqueous solutions to determine the type whether acidic, basic or neutral, this value is represented by a scale which ranges from 0 – 14

Usage Measuring the value of pH of the solutions is very important in the chemical and biochemical reactions, because pH value determines if the solution is **acidic**, **basic** or **neutral**.

if pH < 7	if pH = 7	if pH > 7
The solution is acidic	*The solution is neutral*	*The solution is basic or alkaline*

* The value of pH is measured by :

A pH test paper

- It is a porous paper that is saturated with a pH indicator solution and then dried.
- When this paper is dipped in the solution being tested, it acquires a certain color which indicates a certain pH value.

A solution of pH value = 7

B pH-meter

- It is a digital apparatus which when immersed in the solution being tested, the pH value appears directly on the digital screen.
- The digital pH meter is more accurate than pH test paper in determining pH value of the different solutions, because pH value appears on its screen.

A solution of pH value = 3.2

Questions ? Unit 1 Chapter One

Preliminary questions to remember the main concepts of the lesson

Answer them yourself

1 Choose the correct answer :

(1) All the following are contributions of chemistry in the production of the crops, except ....

a. producing suitable fertilizers.

b. the chemical analysis of the soil.

c. expecting weather conditions.

d. producing effective insecticides and pesticides.

(2) The science which studies the chemical structure of the carbohydrates in wheat plant is ....

a. biochemistry. b. biology.

c. physical chemistry. d. agriculture.

(3) Understanding and studying metabolism in living organisms represent the contributions of chemistry with ....

a. biology. b. physics.

c. agriculture. d. environment.

(4) The measuring tool which is used to measure the volumes of the liquids accurately is ....

a. flask. b. beaker.

c. pipette. d. graduated cylinder.

(5) Which of the following is used in the processes of preparation and distillation ?

a. Burette. b. Pipette.

c. Sensitive balance. d. Round-bottom flask.

(6) Pipette which is used in measuring and transferring dangerous substances has ....

a. graduation. b. one bulb.

c. two bulbs. d. suction tool.

(7) Quantitative measurement ....

a. includes a numerical value and a measuring unit.

b. doesn't include a numerical value.

c. always includes a comparison.

d. is achieved through practical experiments.

2 Complete the following table :

	Tool	Its function
(1)	....	Determining the volumes of liquids and the irregular solid objects.
(2)	....	Mixing the liquids and the solutions.
(3)	....	Adding accurate volume of liquids during titration.
(4)	....	Preparing standard solutions with a high accuracy.

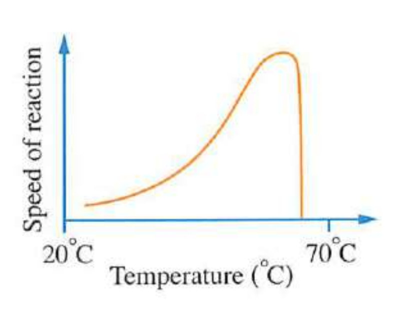
Open book questions

Answered

Multiple choice questions

Chemistry is the central science

1 **The opposite graphical figure represents the effect of temperature on the activity of one of the human digestive enzymes, this represents the integration between chemistry and ....**



(a) physics.
(b) biology.
(c) pharmacy.
(d) agriculture.

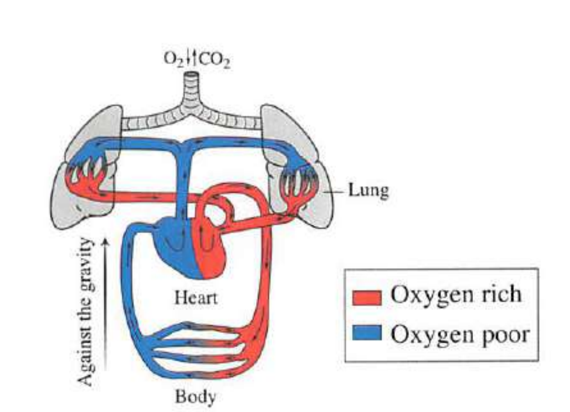
2 **The science which is interested in studying the conversion of the liquid water to water vapour and vice versa in order to preserve the equilibrium in nature is the ....**

(a) environmental chemistry.
(b) organic chemistry.
(c) analytical chemistry.
(d) physical chemistry.

3 **Most of the semi-solid paints become liquefied by the effect of the movement force caused by the paint brush used in painting.**
The previous statement exhibits a kind of integration between chemistry and ....

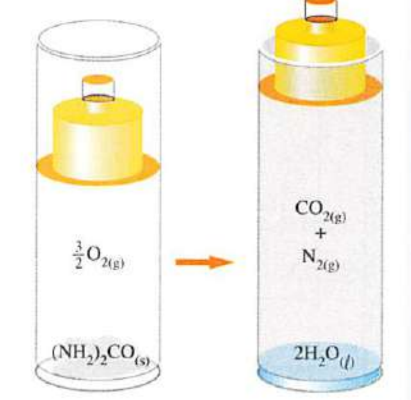
(a) physics.
(b) mathematics.
(c) biology.
(d) agriculture.

4 **The opposite figure represents the human circulatory system, this figure illustrates some sort of combination between ....**



(a) chemistry and medicine only.
(b) chemistry and pharmacy only.
(c) chemistry, medicine and physics.
(d) chemistry, pharmacy and physics.

5 Urea $(NH_2)_2CO$ reacts with oxygen gas O_2 to form carbon dioxide gas CO_2, nitrogen gas N_2 and water H_2O, the total volume of the produced gases is larger than the reactants volumes under the same conditions. What is the science which is interested in studying this kind of reactions ?



(a) Biochemistry.

(b) Physical chemistry.

(c) Environmental chemistry.

(d) Analytical chemistry.

6 What is the science which is interested in the separation processes and the detection of the components of the substance qualitatively and quantitatively ?

(a) Organic chemistry.

(b) Biochemistry.

(c) Analytical chemistry.

(d) Environmental chemistry.

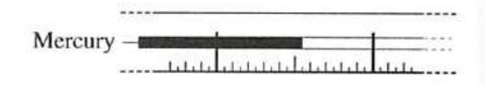
7 Chemical engineers work at new factories including these which produce all the following, <u>except</u> the ....

(a) metals. (b) cosmetics.

(c) tyres. (d) seeds.

Importance of measurement in chemistry

8 A teacher covered the scale of a mercury thermometer to test the ability of a student to measure the boiling point of an unknown liquid. Which of the following represents the boiling point of that liquid, knowing that its boiling point is lower than that of water ?



(a) 75.5°C

(b) 84.5°C

(c) 104.5°C

(d) 105.5°C

9 Which of the following is incorrect regarding the importance of measurement ?

Choices	Importance	Example
(a)	Monitoring	Determination of aspirin dose for a child.
(b)	Health care	Monitoring glucose in the blood of a diabetic patient.
(c)	Information	The proportions of the components of a milk package.
(d)	Management	Adding a basic substance to highly acidic soil.

10 The following tables represent 2 labels showing the nutritional components of 2 cans :

Nutrition Facts	
Fats	1 g
Sugar	8 g
Proteins	4 g
Vitamin D	11%
Iron	55%
Vitamin A	44%
Vitamin B_6	44%
Vitamin B_{12}	100%
Magnesium	22%
Zinc	28%

Can (1)

Nutrition Facts	
Fats	1 g
Sugar	14 g
Proteins	1 g
Vitamin D	28%
Iron	14%
Vitamin A	21%
Vitamin B_6	35%
Vitamin B_{12}	35%
Magnesium	0
Zinc	14%

Can (2)

Which of the following represents the can that contains the least percentage of minerals ? What is this percentage ?

Choices	Can	Percentage of minerals
(a)	(1)	28%
(b)	(1)	13%
(c)	(2)	16%
(d)	(2)	28%

11 The following table shows the food components in 4 meals, the mass of each meal is 100 g :

The meal	Proteins	Fats	Carbohydrates	Sugar	Fibers
A	8.8 g	7.5 g	62.5 g	3.1 g	18.1 g
B	12 g	2.5 g	48 g	12.3 g	25.2 g
C	13 g	6.5 g	60.2 g	10.2 g	10.1 g
D	15.5 g	5 g	50 g	9.5 g	20 g

Which of these meals causes more weight gain when eaten a lot ?

(a) A (b) B (c) C (d) D

12 The following table shows the daily average of the different components of a meal which are obtained by the individuals A , B , C and D :

Individual	Nutritional components in the meal					
	Carbohydrates	Proteins	Fats	Calcium	Iron	Vitamin C
A	590 g	350 g	110 g	2 g	15 mg	95 mg
B	300 g	180 g	200 g	5 g	4 mg	100 mg
C	500 g	120 g	50 g	0.1 g	30 mg	10 mg
D	40 g	65 g	20 g	3 g	20 mg	80 mg

Which of these individuals suffers from anaemia ?

(a) A (b) B

(c) C (d) D

13 A diabetic patient had a breakfast composed of half a bread loaf, 200 g of potato, 4 spoons of beans and one medium apple, if you know that this patient needs to be injected by 2 units of insulin for each carbohydrate unit.

How many units of insulin are needed by the patient for this meal of breakfast ?

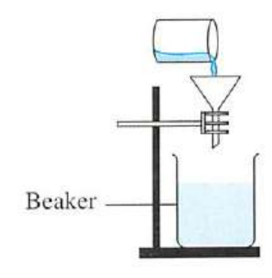
One carbohydrate unit in each of :
$\frac{1}{4}$ of a bread loaf
100 g potato
4 spoons of beans
1 medium apple

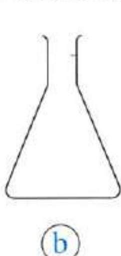
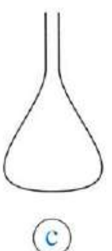
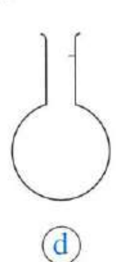
(a) 2 units. (b) 4 units.

(c) 8 units. (d) 12 units.

Measuring tools

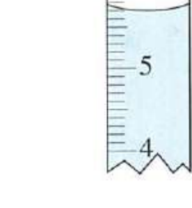
14 In the opposite figure, a mixture of sand and water was poured in a funnel containing a filter paper, to measure the volume of water in this mixture. Which of the following tools can be used instead of a beaker to measure the volume of water accurately ?

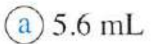


(a) (b) (c) (d)

15 What is the volume of the liquid in the graduated cylinder which is illustrated in the opposite figure ?

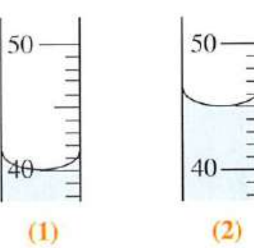




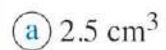
(a) 5.6 mL (b) 5.7 mL

(c) 5.8 mL (d) 5.9 mL

16 Two identical balls were placed in water, which is present in the graduated cylinder figure (1), so the surface of water elevated as in figure (2). What is the volume of the ball ?



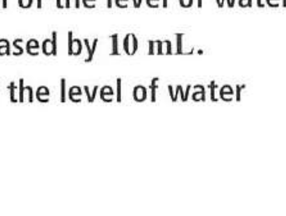
(1) (2)

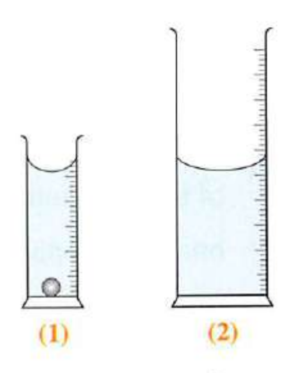


(a) 2.5 cm^3 (b) 5 cm^3

(c) 10 cm^3 (d) 22.5 cm^3

17 On moving the ball from the graduated cylinder (1) to the graduated cylinder (2) the graduation of the level of water which is present in the cylinder (1) decreased by 10 mL. What is the increase in the graduation of the level of water in cylinder (2) ?





(1) (2)

(a) 5 mL (b) 10 mL

(c) 20 mL (d) 40 mL

18 If two balls of the same volume, one of them is of copper and its mass is 8.8 g and the other is of aluminum its mass is 2.7 g , are put in 2 graduated cylinders containing the same volume of water, then the difference in the elevation of water level in the two cylinders will equal ....

(a) zero. (b) 2.7 cm^3 (c) 6.1 cm^3 (d) 11.5 cm^3

19 The opposite figure represents a section in each of a burette and a graduated cylinder (in no particular order or consideration for the diameter of each of them).
Which of the following choices represents the correct readings ?

50 40 30 (X)

27 28 (Y)

Choices	Burette reading (mL)	Graduated cylinder reading (mL)
(a)	44	27.8
(b)	27.8	44
(c)	27.8	42
(d)	28.2	44

20 What is the tool used in preparing potassium hydroxide solution to be used in the determination of the concentration of sulphuric acid ?

(a) Burette.

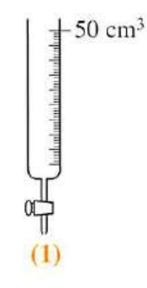
(b) Round-bottom flask.

(c) Beaker.

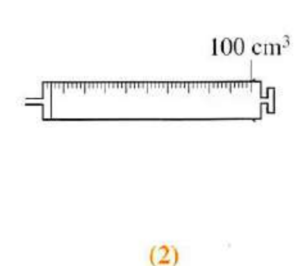
(d) Volumetric flask.

Questions marked by this mark their ideas are explained in the answers

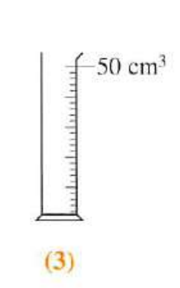
21 The following figures show four measuring tools :



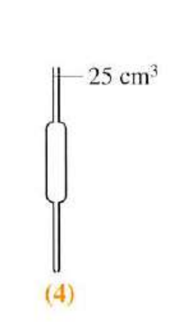
(1)



(2)



(3)

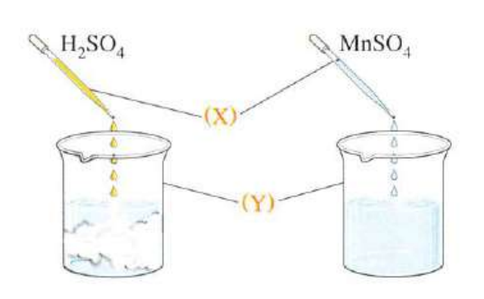


(4)

Which of the following represents the proper use of one of these tools ?

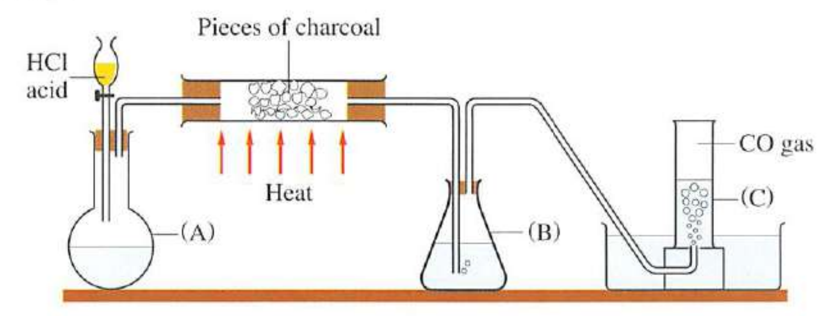
Choices	Tool	Used in measuring
(a)	(1)	16 cm^3 of an acid required to be added to an alkali in a titration.
(b)	(2)	1 cm^3 of an acid required to be added to calcium carbonate in an experiment.
(c)	(3)	75 cm^3 of a gas produced from a thermal decomposition reaction.
(d)	(4)	20 cm^3 of an alkali required to be added to an acid in a titration.

22 The tool (X) is used in transferring two different solutions to the tool (Y), which contains two other different solutions, a precipitate is formed in one of them but not in the other (as shown in the opposite figures) ..
What do you think about the properties of the solutions which are transferred by the tool (X) and about the utility of the tool (Y) ?



Choices	Solutions transferred by the tool (X)	Utility of the tool (Y)
(a)	Safe	Mixing the solutions
(b)	Safe	Determination of the type of the precipitates
(c)	Not safe	Measuring the volumes of the solutions accurately
(d)	Not safe	Mixing the solutions

23 The apparatus shown in the following figure is used in the preparation of CO gas in the laboratory :



Which of the following is correct ?

Choices	Tool (A)	Tool (B)	Tool (C)
(a)	Has a definite capacity	Graduated from the top to the bottom	Made of glass or plastic
(b)	Graduated from the bottom to the top	Used in measuring the volumes of the liquids accurately	Used in estimating the volume of a solid object insoluble in water
(c)	Made of pyrex	Some have definite capacity	Graduated from the bottom to the top
(d)	Used in titrations	Graduated from the bottom to the top	Used in transferring the highly dangerous liquids

24 **A student wants to perform an experiment to measure the time of dissolving 2 g of magnesium completely in 100 mL of hydrochloric acid.**
What are the required tools for this experiment ?

ⓐ Stopwatch, graduated cylinder, sensitive balance.

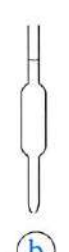
ⓑ Graduated cylinder, thermometer, sensitive balance.

ⓒ Stopwatch, sensitive balance.

ⓓ Stopwatch, graduated cylinder.

25 **One of the students performed an experiment to measure the change in temperature on adding 25 mL of dilute hydrochloric acid to different volumes of sodium hydroxide solution. Which of the following tools the student would not need during the performance of the experiment ?**

ⓐ


ⓑ

ⓒ

ⓓ

26 **5 different solutions are tested with pH paper tapes, they are coloured with the colours illustrated in the opposite table. What is the pair of the acidic solutions ?**

Solution	(A)	(B)	(C)	(D)	(E)
Colour	Orange	Yellow	Green	Blue	Violet
pH	1	3	7	10	14

ⓐ A , B　　ⓑ B , C

ⓒ C , D　　ⓓ D , E

27 **There are two bottles one of them contains an acid and the other contains an alkali, they are required to be identified before being used in a titration.**
What are the required tools for carrying out this experiment ?

ⓐ Pipette, burette, conical flask and pH meter.

ⓑ Pipette, burette, round-bottom flask and pH meter.

ⓒ Glass beaker, graduated cylinder, pipette, burette.

ⓓ Graduated cylinder, pipette, burette, pH meter.

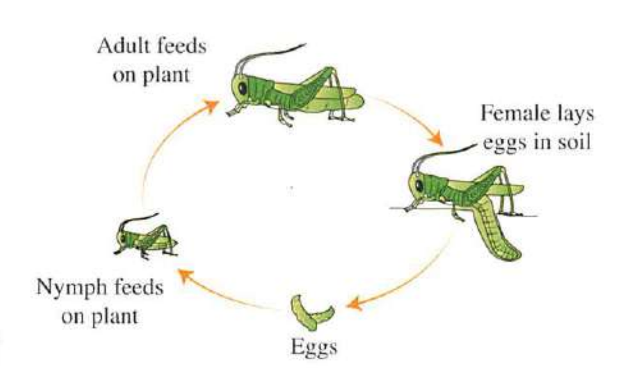
Essay questions

Chemistry is the central science

28 The opposite figure represents the life cycle of the locust :

(1) What is the science which is interested in studying locust egg laying ?

(2) What is the role of chemistry in protecting the harvests from the locust ?



Importance of measurement in chemistry

29 The opposite label is of a nutritional product whose volume is 128 mL :

(1) What is the importance of the presence of this label on the nutritional product ?

(2) Is this package suitable for the nutrition of a skinny person or a fat person ? Explain.

"Knowing that the minimum daily calories needed ranges between 150 : 180 kcal"

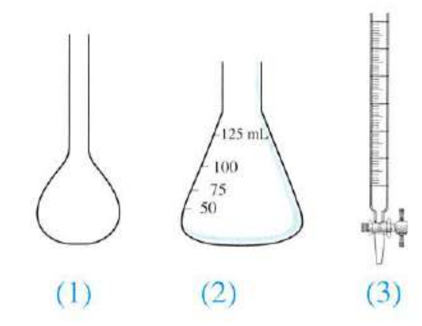
Nutrition facts	
Calories	150 kcal
Fats	0
Sodium	10 mg
Carbohydrates	27 g
Fibers	4 g
Sugar	18 g
Protein	0
Vitamin A	6%
Vitamin C	45%

Measuring tools

30 Study the three tools which are illustrated by the opposite figures, then answer :

(1) What is the difference between the tool (1) and the tool (2) ?

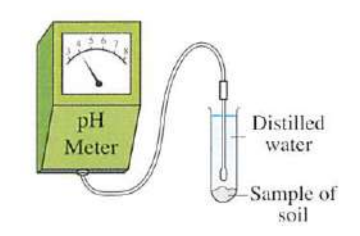
(2) What is the difference between the tool (3) and the pipette ? And what is the similarity between them ?



31 The illustrated device in the opposite figure is used to measure the acidity or the basicity of the agricultural soil :

(1) What is the type of this soil ? Explain.

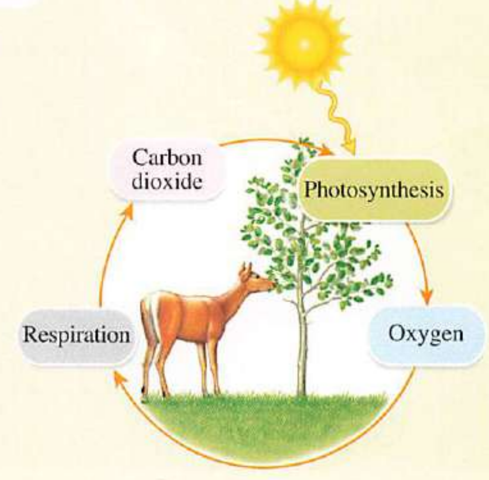
(2) How can this soil be treated ?



New types of questions ?

Choosing two out of five choices questions :

1 **The opposite diagram represents the importance of O_2 and CO_2 gases for sustaining life, the processes show a clear integration between the two sciences ....**



(a) chemistry.
(b) physics.
(c) geology.
(d) biology.
(e) pharmacy.

2 **Which of the following represents quantitative measurement ?**

(a) Sodium chloride is an ionic compound.
(b) The rate of reaction of ionic compounds is fast.
(c) The boiling point of water is 100°C
(d) Nitric acid is a strong acid.
(e) Methane gas contains 75% carbon.

3 **What are the two tools required to measure the density of petroleum oil ?**

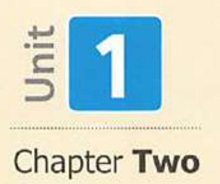
(a) Graduated cylinder.
(b) Round-bottom flask.
(c) Burette.
(d) Volumetric flask.
(e) Digital balance.

4 **Which of the following represents both the burette and the pipette ?**

(a) They are graduated from top to bottom.
(b) They are graduated from bottom to top.
(c) They are made of glass or plastic.
(d) They are used in measuring the volumes of the liquids.
(e) They are used in mixing liquids and solutions.

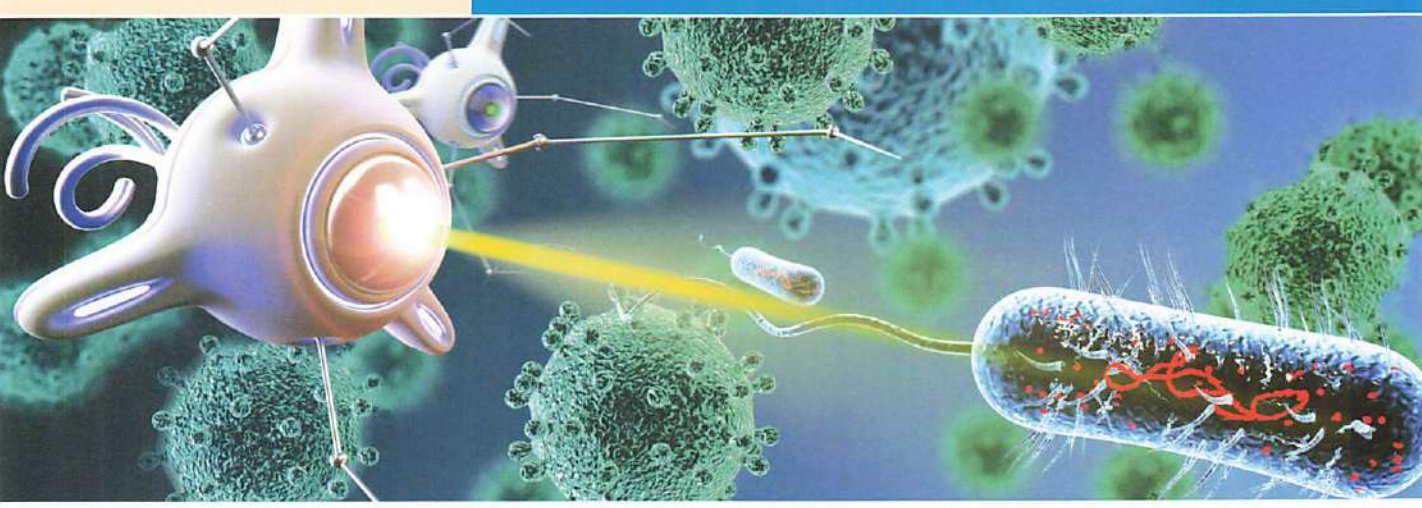
5 **All the following are similarities between the graduated cylinder and the burette, except that ....**

(a) they are used in measuring the volumes of the liquids.
(b) they are used in measuring the volumes of the solid objects.
(c) they are made of glass.
(d) they are graduated tools.
(e) they are used in titration processes.



Chapter **Two**

Chemistry and Nanotechnology



- There are some derived words from the SI basic units differ from each other by powers of ten (decimal exponent 10^n).
  These derived words are called **SI Prefixes.**

Amount	Decimal exponent (10^n)
1000 000	10^6
0.001	10^{-3}

- **The following table shows some of SI Prefixes :**

SI Prefixes	Abbreviation	Multiple (10^n)	Examples
Kilo	k	10^3	1 **Kilo**meter = 10^3 meter 1 km = 10^3 m
Deci	d	10^{-1}	1 **Deci**meter = 10^{-1} meter 1 dm = 10^{-1} m
Centi	c	10^{-2}	1 **Centi**meter = 10^{-2} meter 1 cm = 10^{-2} m
Milli	m	10^{-3}	1 **Milli**meter = 10^{-3} meter 1 mm = 10^{-3} m
Micro	μ	10^{-6}	1 **Micro**meter = 10^{-6} meter 1 μm = 10^{-6} m
Nano	n	10^{-9}	1 **Nano**meter = 10^{-9} meter 1 nm = 10^{-9} m

Which is more harmful,

the concentration of lead in a river water when it equals a part per billion or when it equals a part per million ? Why ?

The more harmful is when it equals a part per million 1×10^{-6} as this amount is larger than when it equals a part per billion 1×10^{-9}

Test Yourself

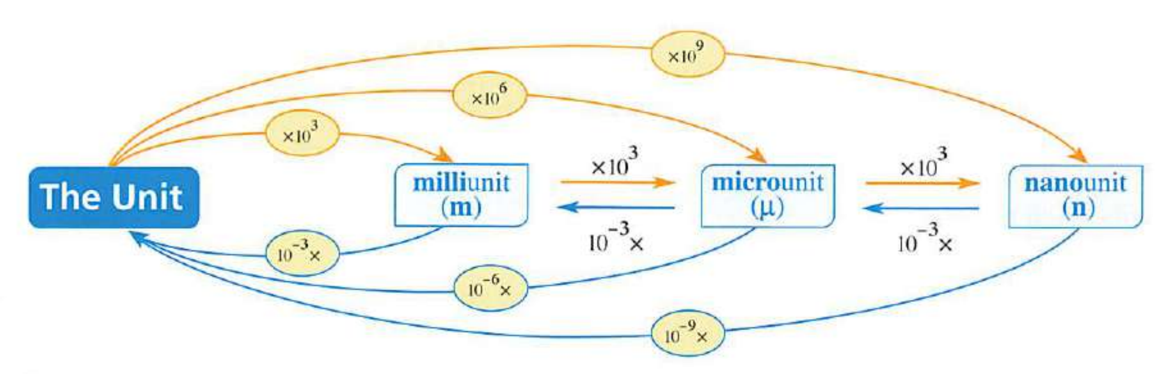
Which of the following measuring relations is incorrect ?

(a) 1 microliter = 1×10^{-6} L
(b) 1 gram = 1×10^{-6} kg
(c) 1 liter = 10^3 mL
(d) 10^2 centigram = 1 g

Answer : The correct choice is ....

The relation between milli , micro and nano

- Milli ($\frac{1}{1000}$ of unit) > micro ($\frac{1}{1000\,000}$ of unit) > nano ($\frac{1}{1000\,000\,000}$ of unit).
- **The following diagram shows how to convert from the measuring unit to its milli, micro or nano and vice versa :**



Worked Examples

1 Which of the following represents the least mass of a chemical powder ?

(a) 100 μg
(b) 1000 ng
(c) 1 mg
(d) 0.01 g

Idea of answering :

(a) 100 μg = 100×10^{-6} g = 1×10^{-4} g
(b) 1000 ng = 1000×10^{-9} g = 1×10^{-6} g
(c) 1 mg = 1×10^{-3} g = 1×10^{-3} g
(d) 0.01 g = 10^{-2} g

Answer : The correct choice is (b)

2 **Uranium is supposed to exist in earth's crust in an average concentration of 4 g for each 1 ton of earth's crust. What is the mass of uranium which exists in 1.5 mg of earth's crust ?**

(a) 6 ng (b) 6 μg

(c) 6 mg (d) 6×10^{-5} g

Idea of answering :

$\because$ 1 ton = 1000 kg , 1 kg = 1000 g , 1 g = 1000 mg

$$\therefore 1 \text{ ton} \times \frac{1000 \text{ kg}}{1 \text{ ton}} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1000 \text{ mg}}{1 \text{ g}} = 1 \times 10^9 \text{ mg}$$

$\therefore$ 1 ton = 1×10^9 mg

Earth's crust	$\xrightarrow{\text{Contains}}$	Uranium
1×10^9 mg		4 g
1.5 mg		? g

$$\therefore \text{The mass of uranium} = \frac{4 \times 1.5}{1 \times 10^9} = 6 \times 10^{-9} \text{ g} = 6 \text{ ng}$$

Answer : The correct choice is (a)

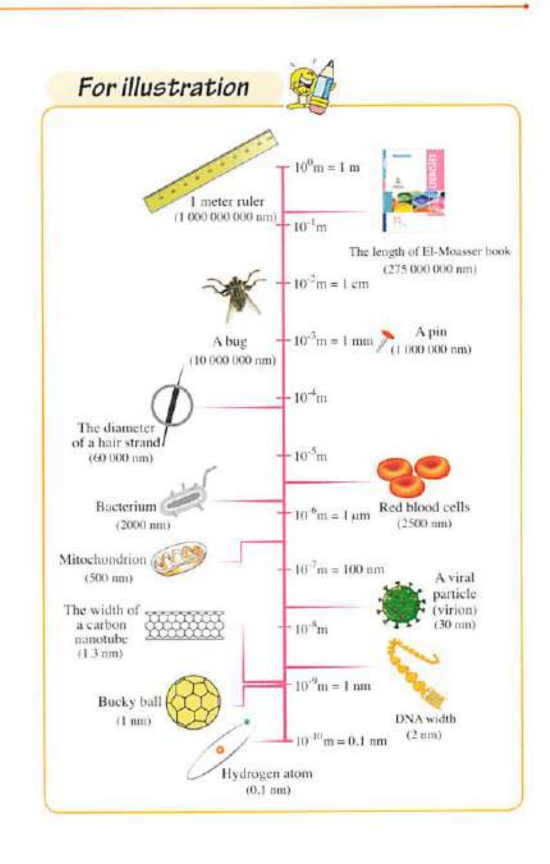
Nano scale

* Nano is a prefix which precedes the measuring units, such as :
  - Nanometer (nm).
  - Nanogram (ng).
  - Nanosecond (ns).
  - Nanojoule (nJ).

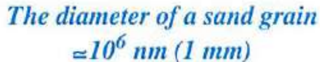
Nano scale is the scale of the extremely small particles whose diameters range between 1 : 100 nm

★ **Substances gain unique properties in the Nano scale differ from their properties in macro or micro scales.**

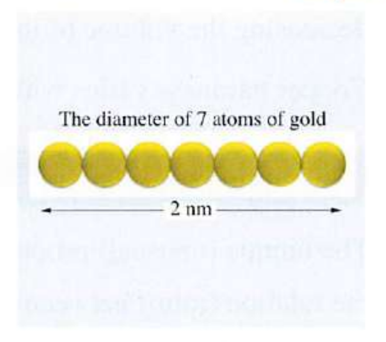
For illustration



- **The following examples show how small the nanometer unit is :**


The diameter of a sand grain $\simeq 10^6$ nm (1 mm)

The diameter of a water molecule is approximately 0.3 nm



The diameter of an atom ranges from 0.1 : 0.3 nm

Critical Nano volume is the volume in which the unique Nano properties of the substance appear, each dimension of this substance is less than 100 nm

- These properties change according to the change in the Nano volume and they are called **Volume dependent properties.**

As the case in :

- **Chemical properties like** the speed of chemical reactions, where the number of atoms of the surface of the substance which is exposed to the reaction (in nano volume) becomes very large compared to the macro volume of the substance.
- **Physical properties like** color, transparency, melting point as well as heat conductivity and electric conductivity.
- **Mechanical properties like** hardness and elasticity.

Examples of Nano properties

A The change of gold color according to the change of the Nano volume

- It's known that gold has a bright yellow color, but on reducing its particles volume to the Nano volume, it takes different colors like : Red, orange, green or blue according to its Nano volume, because the interaction of gold particles in Nano scale with light differs from its interaction with light in macro scale.

Changing the gold color according to its Nano volume

B The change of copper hardness according to the Nano volume

- The hardness of copper increases by decreasing the volume of its particles to be in Nano volume.
- Copper hardness varies with its particles Nano volume.

Nano copper powder

Explanation of the unique (unusual) behavior of Nano substances

- The unique (unusual) properties of Nano substances are due to the relation (ratio) between the surface area and the volume.

Application The relation between the surface area and the volume of a cube.

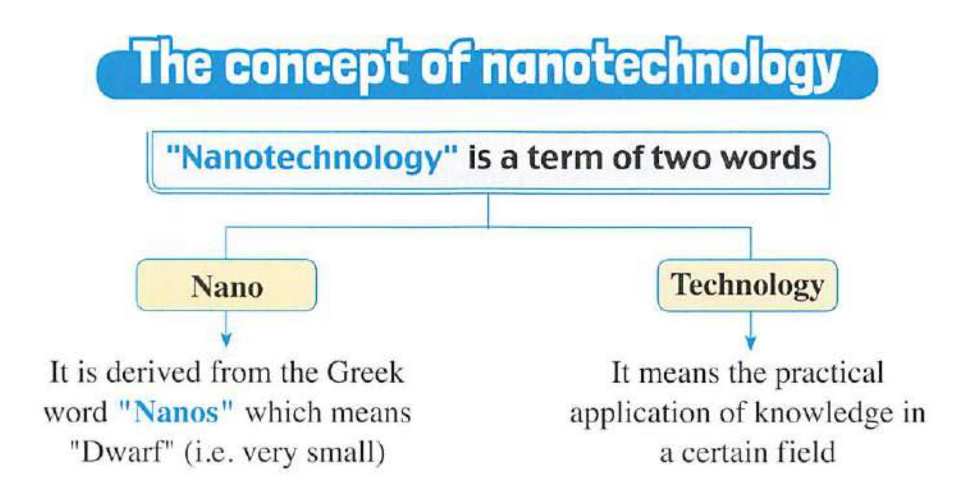
On dividing a cube of a side length 1 cm to many cubes, the total surface area of cubes increases, while the total volume of the cubes is still constant, **as shown in the following table :**

Figures	1 cm	$\frac{1}{2}$ cm	$\frac{1}{3}$ cm
Length of the cube side (L)	1 cm	$\frac{1}{2}$ cm	$\frac{1}{3}$ cm
Number of cubes	1	8	27
Total surface area $= (L^2) \times 6$ faces $\times$ no. of cubes	$(1\ cm)^2 \times 6 \times 1 = 6\ cm^2$	$(\frac{1}{2}\ cm)^2 \times 6 \times 8 = 12\ cm^2$	$(\frac{1}{3}\ cm)^2 \times 6 \times 27 = 18\ cm^2$
Total volume $= (L^3) \times$ no. of cubes	$(1\ cm)^3 \times 1 = 1\ cm^3$	$(\frac{1}{2}\ cm)^3 \times 8 = 1\ cm^3$	$(\frac{1}{3}\ cm)^3 \times 27 = 1\ cm^3$
The ratio between the surface and the volume $= \frac{\text{Surface area}}{\text{Volume}}$	$\frac{6}{1} = 6$	$\frac{12}{1} = 12$	$\frac{18}{1} = 18$

With more division in the cube, the ratio between the surface area and the volume increases, when the particles of the substance become in nano volume, the ratio between the surface area and the volume **will increase** to a very large value.
So it will provide the substance with new and unique physical and chemical properties.

- It is clear that fine powdered sugar dissolves in water faster than a block cube, in the same amount of water and at the same temperature, **because** sugar powder has a greater ratio between the surface area and the volume than that of a sugar cube. So more number of molecules will be exposed to the dissolving process at the same time.

The concept of nanotechnology

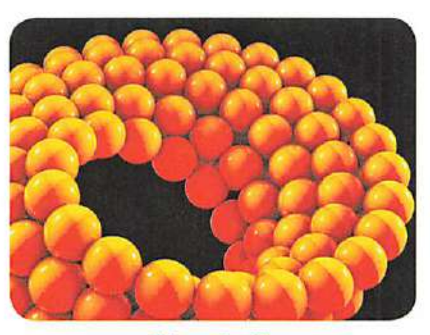


Nanotechnology can be defined as the technology of very small substances and it deals with the substances in the Nano scale to produce new substances with new, useful and unique properties.

Nanochemistry

Nanochemistry : It is one of **the Nano science branches** **which :**

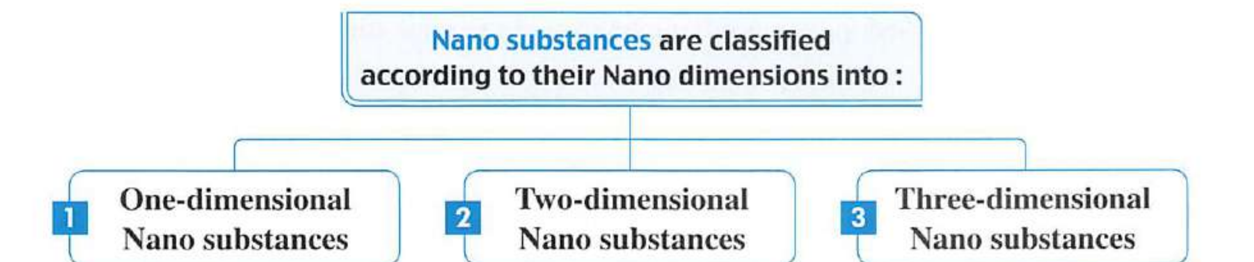
1. Deals with chemical applications of Nano substances.
2. Includes studying, describing and the synthesis of Nano substances.
3. Studies the unique properties related to collecting atoms and molecules which have Nano dimensions.


Nano balls

Nano substances may take different shapes as follows

- **Particles.**
- **Nano columns.**
- **Nano wires.**
- **Balls.**
- **Nanotubes.**
- **Nanofibers.**
- **Thin films.**
- **Thin membranes.**

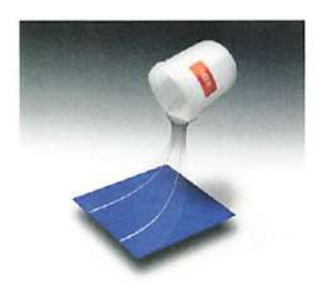
• Any substance, no matter how small its volume is, has three dimensional structure (length, width and height)



1 One-dimensional Nano substances

One-dimensional Nano substances are Nano substances that have one Nano dimension.

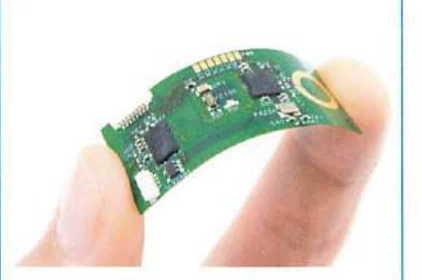
Thin films



Used in

1. Packaging food products to protect them from getting spoiled or rotten.
2. Painting surfaces to protect them from rusting and corrosion.

Nano wires



Used in

Manufacturing electric circuits

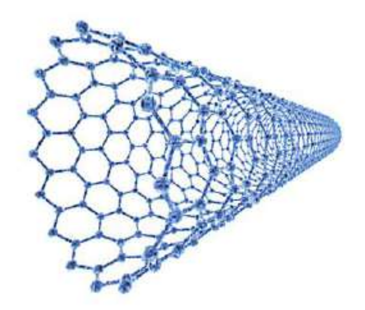
Nanofibers

Production of water filters

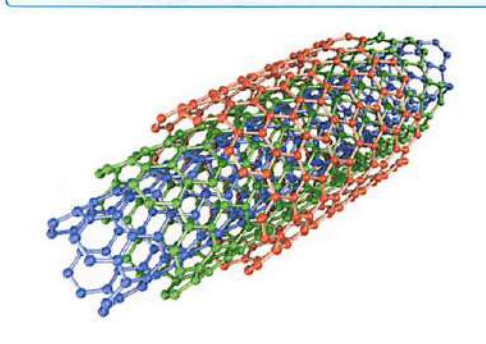
2 Two-dimensional Nano substances

Two-dimensional Nano substances are Nano substances that have two Nano dimensions.

Single-walled carbon Nanotube

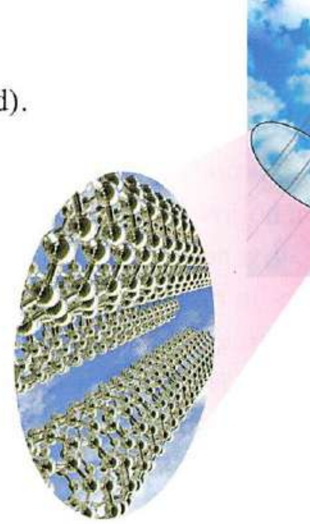


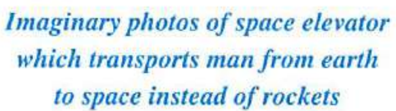
Multi-walled carbon Nanotube



Carbon Nanotubes are :

1. Good conductors (superconductors) of electricity (where their conductivity exceeds that of copper).
2. Good conductors (superconductors) of heat (where their conductivity exceeds that of diamond).
3. Stronger and lighter than steel, due to the powerful bonds between their molecules, therefore the Nanotubes which have the size of a human hair can easily pull a truck. Therefore, scientists think of inventing very strong robes that can be used in the future to make space elevators (shuttles).
4. Connected easily to protein. Therefore, they can be used in making biological sensor devices which are sensitive to certain molecules.




Imaginary photos of space elevator which transports man from earth to space instead of rockets

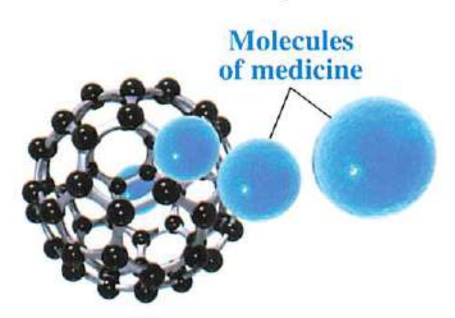
3 Three-dimensional Nano substances

Three-dimensional Nano substances are Nano substances that have three Nano dimensions.

Bucky ball C60

Bucky ball C60
Each carbon atom is linked to three carbon atoms

1. Bucky ball C60 consists of 60 carbon atoms.
2. It is characterized by a group of special properties, which depend on its molecular structure.
3. The molecular model of the bucky ball appears as a hollow football. So scientists test the effectiveness of using it as a carrier for medicines in the body,
as its hollow structure allows it to hold the molecules of medicine inside it and protects them from the reaction with other molecules inside the body.



Nano shell

Core
Shell

Used in treating cancer

For illustration

Nano shell consists of :
1. **Core :** It is made of insulating substances.
2. **Shell :** It is made of very thin metallic cover (almost gold).

Worked Example

The following table shows the dimensions of four different substances (A), (B), (C), and (D) :

Substance	Length	Width	Height
(A)	1.2×10^{-8} m	200×10^{-10} m	322×10^{-10} m
(B)	21×10^{-10} m	0.18×10^{-5} m	17.9×10^{-9} m
(C)	130×10^{-7} m	49×10^{-7} m	68×10^{-6} m
(D)	1.7×10^{-8} m	83×10^{-4} m	96×10^{-3} m

What is the correct ascending order of these substances according to their hardness ?

(a) A > B > C > D

(b) D > A > C > B

(c) A > B > D > C

(d) D > C > A > B

Idea of answering :

It is necessary to convert the measuring units of the dimensions from (m) to (nm) by multiplying $\times 10^9$

Substance	Length	Width	Height
(A)	12 nm	20 nm	32.2 nm
(B)	2.1 nm	1800 nm	17.9 nm
(C)	13×10^3 nm	4900 nm	68×10^3 nm
(D)	17 nm	83×10^5 nm	96×10^6 nm

∵ Nano scale ranges between 1 : 100 nm

∴ These 4 substances are classified as shown :

(A)	Three - dimensional nano substance
(B)	Two - dimensional nano substance
(C)	It is not a nano substance
(D)	One - dimensional nano substance

∵ The hardness of the substance increases by increasing the dimensions of its nanoparticles.

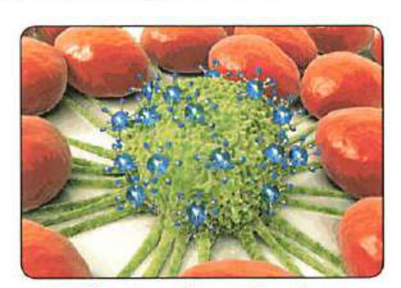
∴ The correct ascending order of the substances according to their hardness is : A > B > D > C

Answer : The correct choice is (c)

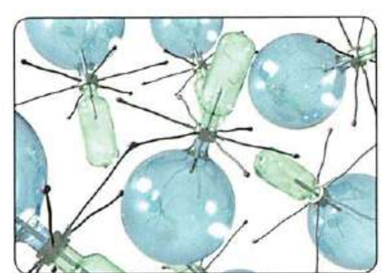
Applications of Nanotechnology

A Medical field

1. The early diagnosis of diseases and picturing of organs and tissues.
2. Accurate delivering of a medicine to the infected tissues and cells, which increases the chances of healing and decreases the harmful side effects of the traditional healing methods which don't distinguish between the infected cells and the other healthy ones.
3. Producing **Nanorobots** that enter the body through the bloodstream to **remove blood clots** from the vein walls without surgical interference.



Delivering the medication to the infected cells by a nanorobot



Removing cancerous cells by a nanorobot

4. Producing extremely small devices for **dialysis** that are implanted in the body of the patient who suffers from kidney failure.

B Agricultural field

1. Preserving food.
2. Identifying bacteria which are found in nutrients.
3. Improving nutrients, pesticides and medicines for plants and animals with special features.

C Energy field

1. Producing **solar cells** by using **Nano silicon** which has a great ability to convert solar energy into electrical energy and avoid the leakage of heat energy.
2. Producing **hydrogen fuel cells**, with a high performance and low cost.

Solar cells with Nano silicon

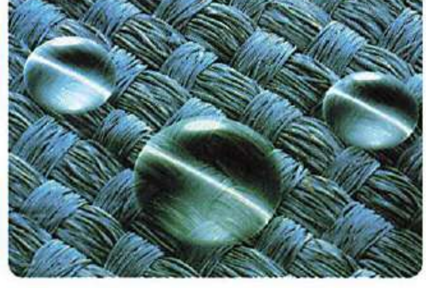
D Industrial field

1. Producing invisible Nano molecules, which give the glass and ceramics the property of self-cleaning.

2. Producing Nano substances to purify sun rays from ultraviolet rays in order to improve sunblock cosmetics and creams.

3. Producing Nano wrapping technology in the form of paints and sprays to protect the screens of electrical devices from scratching.

4. Producing dirt removing fabrics that are characterized by the self-cleaning property.



Dirt removing nano-textile

E Communications field

1. Producing wireless Nano devices, mobiles and satellites.
2. Decreasing the size of transistors.
3. Producing electronic chips that are characterized by a high storage capacity.

For illustration

Transistor is a semiconductor device, used in most electrical devices to control the flow of the electric current.

F Environmental field

Producing Nano filters which are used in :

1. Purification of air and water.
2. Desalination of water.
3. Solving the nuclear wastes problem.
4. Elimination of the dangerous elements from the industrial wastes.

The possible harmful effects of Nanotechnology

A Environmental effects

During the production of Nano substances, there are many wastes which can be very dangerous, because they may be suspended in air, then enter water and soil and they may easily penetrate the animal and plant cells, this is called **Nano pollution** *which is the pollution caused by the wastes produced from preparing Nano substances, it affects each of water, air, soil and even the climate.*

B Medical effects

The very minute Nanoparticles may penetrate the body of human or animal through the cell membrane of the skin and lungs causing diseases.

C Social effects

The social and economic problems between the rich world countries and the developing countries may increase, due to the unequal distribution of technology and economic resources.

Preliminary questions to remember the main concepts of the lesson

Answer them yourself

1 Choose the correct answer :

(1) Which of the following represents the change in the surface area and the volume of a cube of sugar when it is grinded ?

Choices	Surface area	Volume
a.	Increases	Increases
b.	Does not change	Does not change
c.	Increases	Does not change
d.	Does not change	Increases

(2) The reason of the new unique properties of the nano substances is the very large ratio between volume and ....

a. length. b. density. c. mass. d. surface area.

(3) All the following are one-dimensional nano substances, except ....

a. thin films. b. nano wires. c. nano fibers. d. nano shell.

(4) From the two-dimensional nano substances is (are) ....

a. carbon nanotubes. b. bucky ball.

c. nano shell. d. nano fibers.

(5) The substance which can be used as a carrier for a medicine in the body is ....

a. nano shell. b. nano silicon. c. bucky ball C60 d. nano fiber.

(6) From the modern technologies in treating coronary artery blockage is ....

a. the bucky ball. b. the nanorobot.

c. the nano shell. d. a carbon tube.

(7) From the applications of nanotechnology in the environmental field are ....

a. wireless nano devices. b. nano filters.

c. dirt removing textile. d. hydrogen fuel cells.

2 Give reasons for :

(1) Nano is a unique scale.

(2) The color of gold changes when the dimensions of its particles change from macro scale to nano scale.

(3) Carbon nanotubes are stronger than steel.

(4) The bucky ball is denoted by C60

(5) Nanotechnology may violate the principle of equality.

3 What are the results of :

(1) Reducing the volume of gold particles to the nano volume.

(2) Reducing the volume of copper particles from macro scale to nano scale.

(3) The penetration of the very minute nanoparticles to the cell membranes of the skin, then to the body.

Steady

Open book questions

Answered

Multiple choice questions

Prefixes

1 **What is the value of 0.03 s in nanoseconds ?**

(a) 3×10^9 ns (b) 3×10^7 ns

(c) 3×10^5 ns (d) 3×10^3 ns

2 **Which of the following substances has the largest mass ?**

(a) 1000 mg of gold. (b) 1 kg of rice.

(c) 10000 g of meat. (d) 10000 mg of feather.

3 **The amount 0.398 m equals ....**

(a) 398 mm (b) 3.98×10^{-3} mm

(c) 3.98×10^{-4} mm (d) 0.0398 mm

4 **What is the value of 15.7 mL of a liquid in nanoliters ?**

(a) 157 nL (b) 2.62 nL

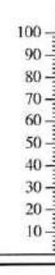
(c) 1.57×10^7 nL (d) 1.57×10^{-5} nL

5 **Which of the following pairs of masses is equal ?**

(a) 10^2 µg / 10^8 ng (b) 10^8 ng / 0.1 mg

(c) 0.1 mg / 0.001 g (d) 10^2 µg / 0.1 mg

6 **The opposite figure shows a graduated cylinder. What is the suitable measuring unit which is used to measure the volumes in the graduated cylinder ?**



(a) mm^2 (b) mm^3

(c) cm^2 (d) cm^3

7 **A doctor has prescribed 0.125 g of ampicillin for a patient, if each 5 mL of the ampicillin syrup medication contains 250 mg of ampicillin. What is the volume which is required for the patient in each dose ?**

(a) 5 mL

(b) 2.5 mL

(c) 1.25 mL

(d) 0.75 mL

Questions marked by this mark their ideas are explained in the answers

Nano scale

8 **Which of the letters which are illustrated on the opposite graphical figure represents the critical nano volume of the particles of a nano substance ?**

(a) A (b) B

(c) C (d) D

Hardness

Particle volume (nm^3)

A B C D

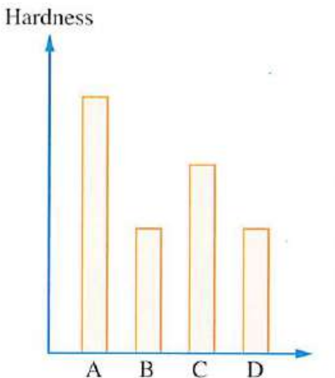
9 **The opposite figure represents the hardness of 4 nanostates of a sample of an element.**
Which of these states its total surface area is the largest ?

(a) A

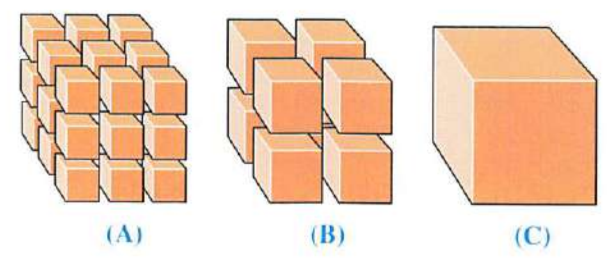
(b) B

(c) C

(d) D



10 **The following figures represent 3 samples of the same substance, the mass of each of them is 50 g, when they were dissolved in 500 mL of water - each individually - at room temperature, it was found that the rate of dissolution of the sample (C) is the lowest.**



(A) (B) (C)

What is the scientific explanation for that ? The sample (C) has the ....

(a) largest volume. (b) smallest surface area.

(c) highest number of particles. (d) lowest density.

Nanochemistry

11 **To be described as a nano particle, this particle should ....**

(a) be unidimensional.

(b) have length and width which are measured in nano scale.

(c) have length, width and height.

(d) have at least one nano dimension.

12 The screen of the mobile phone is covered with nano liquid to form a thin layer on its surface to protect it from scratching and breaking.
What is the type of the material used in manufacturing this nano liquid ?

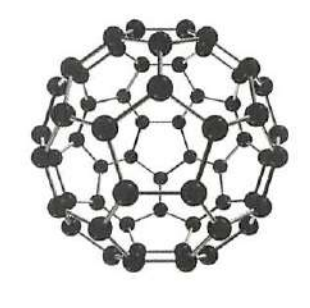
(a) Colloidal substance.
(b) One-dimensional nano substance.
(c) Suspended substance.
(d) Two-dimensional nano substance.

13 Which of the following choices expresses the dimensions of a two dimensional nano substance ?

Choices	Length	Width	Height
(a)	1.2×10^{-11} m	200×10^{-10} m	320×10^{-12} m
(b)	21×10^{-10} m	0.18×10^{-5} m	17.9×10^{-9} m
(c)	130×10^{-7} m	49×10^{-7} m	68×10^{-6} m
(d)	17×10^{-8} m	83×10^{-4} m	96×10^{-3} m

14 What are the possible dimensions of the opposite figure ?

Choices	Length	Width	Height
(a)	322 nm	83 nm	720 nm
(b)	179 nm	180 nm	11 nm
(c)	86 nm	94 nm	91 nm
(d)	196 nm	201 nm	278 nm



15 If the nanodimensions of the bucky ball are :
(86×10^{-9} m / 9×10^{-8} m / 910×10^{-10} m)
Which of the following represents the possible dimensions of the particles of the medicine transferred by this ball ?

Choices	Length	Width	Height
(a)	86 nm	94 nm	910 nm
(b)	86 nm	90 nm	91 nm
(c)	250×10^{-10} m	27 nm	180×10^{-10} m
(d)	650×10^{-9} m	9×10^{-7} m	98 nm

16 **What is the number of carbon atoms which are linked to each carbon atom in each of bucky ball, and the carbon nanotube ?**

Choices	In bucky ball	In carbon nanotube
(a)	3	3
(b)	2	3
(c)	3	2
(d)	6	6

17 **What is the difference in the bonding of carbon atoms with each other in each of bucky ball, and the carbon nanotube ?**

Choices	Carbon atoms of bucky ball	Carbon atoms of the carbon nanotube
(a)	bound to each other forming pentagons	bound to each other forming hexagons
(b)	bound to each other forming hexagons	bound to each other forming pentagons
(c)	bound to each other forming pentagons and hexagons	bound to each other forming hexagons
(d)	bound to each other forming hexagons	bound to each other forming pentagons and hexagons

18 **One of the uses of the three-dimensional nano substances is to ....**

(a) manufacture nanorobots.

(b) target the infected cells with the proper medication.

(c) target crawling insects.

(d) manufacture geological scanners.

Applications of nanotechnology

19 **Nano particles which are covered with gold are used in the treatment of ....**

(a) visual impairment.

(b) athlete's foot.

(c) breast cancer.

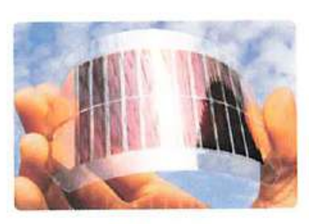
(d) round worm.

20 **In the light of the interest of the scientists in reducing the consumption of the aviation fuel, there are attempts being made to replace the copper conductors with plastic conductors known as polyaniline.**
Which of the following can be added to polyaniline to render it a better electric conductor than copper ?

(a) Carbon nanotubes. (b) Bucky ball.
(c) Nano shell. (d) Nano wires.

21 **The opposite figures represent two solar cells, if these two cells are operated for the same period of time, then ....**

Ordinary solar cell
(A)



Solar cell of nanosilicon
(B)

(a) the temperature of the cell (A) is equal to that of the cell (B).
(b) the temperature of the cell (A) is lower than that of the cell (B).
(c) the quantity of the electricity generated from the cell (A) is larger than that generated from the cell (B).
(d) the quantity of the electricity generated from the cell (A) is less than that generated from the cell (B).

Essay questions

Prefixes

22 **There are 5 different physical quantities :**

$2\ m^3$	0.5 g	0.5 kg	$600\ cm^2$	20 mm

Use the scientific sense to determine the suitable unit for each of the following :

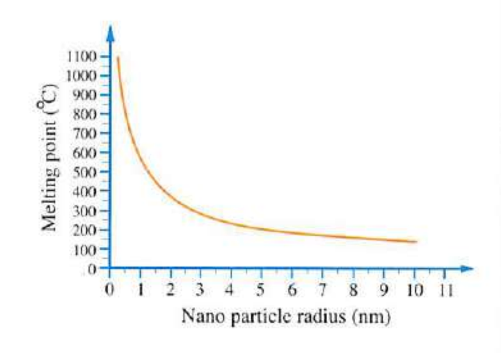
(1) The mass of a small paper clip. **(2)** The length of a small paper clip.
(3) The volume of a freezer in a refrigerator. **(4)** The surface area of a book cover.
(5) The mass of a jam jar.

23 **Calculate the quantities produced from converting :**

(1) 1.445 m to km **(2)** 2.41 cm to m
(3) 235.3 m to mm **(4)** 903.3 nm to µm
(5) 8.43 cm to mm **(6)** 294.5 nm to cm

Nano scale

24 **Study the opposite graph, then answer the following :**



(1) What is the relation between the melting points of nano substances and their particles radii ?

(2) Which is higher the melting point of silver particles in micro scale or nano scale ?

25 **The opposite figure represents** two types of gold rings, rings (1) are red, while ring (2) is golden. **What is the scientific explanation** of the red colour of the rings (1) ?

Nanochemistry

26 Sesame seeds are characterized by containing a large amount of oil, equals approximately half the mass.

Tahini is the blend produced from the solid substances which result from the fine grinding of the roasted sesame seeds and the oil that is yielded from them, in the light of your understanding of the unique properties of nano substances, **illustrate the reason of the different taste of tahini from the taste of sesame of which it is made.**

27 **The following table shows the three dimensions of four different substances :**

Substance	Length	Width	Height
(W)	17×10^{-8} m	83×10^{-4} m	96×10^{-3} m
(X)	111.2×10^{-11} m	201×10^{-10} m	3332.2×10^{-12} m
(Y)	21×10^{-10} m	0.18×10^{-5} m	17.9×10^{-9} m
(Z)	130×10^{-7} m	49×10^{-9} m	68×10^{-6} m

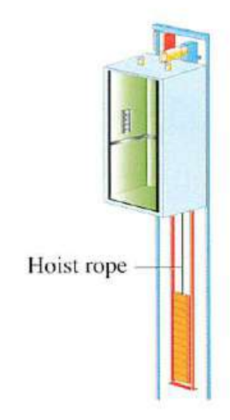
Mention the symbol of the substance which is :

(1) Not a nano substance.

(2) One-dimensional nano substance.

(3) A gold nano shell.

28 The opposite figure shows an elevator car which is suspended by the hoist rope, which is made of braided steel which in turn is formed of strands, each strand has a diameter ranges between 6 : 11 mm, **what is the future alternative of the steel rope which is characterized by the following properties :**

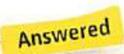


- It is much lighter than steel.
- Its diameter = 60000 nm (a hair strand diameter).

29 Bucky ball can be used in storing hydrogen gas which is used as fuel in some modern cars, **why is the molecular model of bucky ball eligible for storing hydrogen ?**

30 **The opposite illustrative figure** shows a nanorobot that Dr. Magdi Yacoub dreams to use in his field to carry out operations without surgery. **Suggest a medical importance for the nanorobot.**

New types of questions



Choosing two out of five choices questions :

1 Which of the following substances can have these dimensions ?

0.11×10^{-10} m	0.18×10^{-5} m	320×10^{-11} m

(a) thin films.
(b) bucky balls.
(c) carbon nanotubes.
(d) nano wires.
(e) nano shells.

2 The substance whose dimensions are : (196 nm / 87 nm / 91 nm) can be used in ....

(a) producing water filters.
(b) making space elevators.
(c) covering car roofs.
(d) delivering medicine to infected cells.
(e) making biological sensor devices.

3 The dimensions of the particles of a substance are : (79 nm / 92 nm / 81 nm) Its molecule is composed of 60 similar atoms, two characteristics of this substance are ....

(a) its electrical conductivity.
(b) its high hardness.
(c) its inertness to human body.
(d) that it is hollow.
(e) that it binds easily to protein.

4 If one of the dimensions of the substance used in curing cancer is X = 30 nm What are the possible dimensions Y and Z of this substance ?

(a) 10^{-3} nm
(b) 10 nm
(c) 10^{3} nm
(d) 30 nm
(e) 300 nm

Exam model on Unit 1

Choose the correct answer for the questions 1 : 10 .... 10 marks

1 **A student wanted to calculate the speed of the reaction of diluted sulphuric acid with a definite mass of zinc at 35°C, so he prepared a bottle of the acid and a glass beaker.**

What are the other tools that are required for this experiment ?

(a) Sensitive balance, stopwatch and graduated cylinder.

(b) Sensitive balance, stopwatch and thermometer.

(c) Flask, graduated cylinder and thermometer.

(d) Stopwatch, graduated cylinder and thermometer.

2 **Which of the following represents graduated cylinder, burette, pipette and the flask correctly ?**

Choices	Graduated cylinder	Burette	Pipette	Flask
(a)	Used in heating liquids	Graduated from top to bottom	Some have definite capacity	May have 1 L capacity
(b)	Used in collecting gases	Measures the volumes of gases	May be provided by a suction tool	May be rounded
(c)	Graduated from bottom to top	Graduated from top to bottom	Graduated from top to bottom	Made of plastic
(d)	Graduated from bottom to top	Used in titrations	Some are graduated	Able to be heated

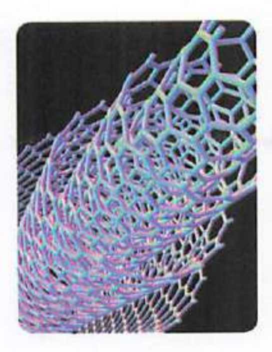
3 **Substances (A) and (B) which are illustrated in the opposite figure are nano substances, they are similar in being ....**

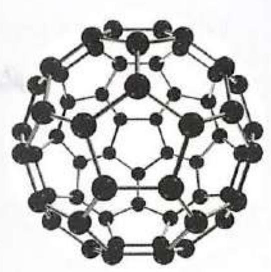
(a) three-dimensional nano substances.

(b) two-dimensional nano substances.

(c) multi-dimensional nano substances.

(d) one-dimensional nano substances.


(A)


(B)

4. **The volume of nano shell and the thickness of gold nano layer which covers the shell affect ....**

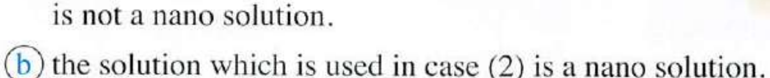
(a) its density.

(b) its colour.

(c) its odour.

(d) its taste.

5. **Two different shoes are dipped in two dyes, one of them is coloured by the dye and the other is not, as shown in the figure, this is explained by the fact that ....**



(1) (2)

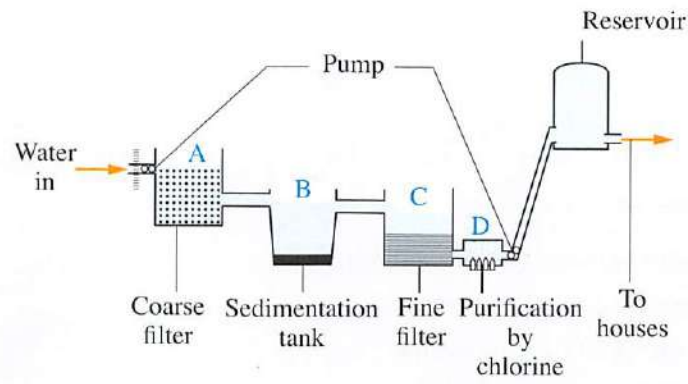
(a) the solution which is used in case (1) is not a nano solution.

(b) the solution which is used in case (2) is a nano solution.

(c) the shoe which is used in case (1) is made of plastic.

(d) the shoe which is used in case (2) is covered with a stain repellent nano substance.

6. **The main source for drinkable water in Egypt is the river of the Nile, so to separate and dispose the particles of silt, chemical substances and bacteria which exist in it, purification and treatment of water are carried out in several stages (illustrated in the following figure) :**

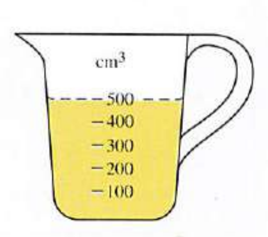


In which of these tanks are the nano fibers used ?

(a) A　　(b) B

(c) C　　(d) D

7. **The quantity of oil in the opposite vessel equals ....**



(a) 5×10^4 mm^3

(b) 5×10^{-4} m^3

(c) 5×10^{15} μm^3

(d) 5×10^{22} nm^3

8 **What is the science which is interested in studying the composition of matter, the change in energy and the laws which explain the conversion of matter from one form to another ?**

(a) Inorganic chemistry.

(b) Organic chemistry.

(c) Analytical chemistry.

(d) Physical chemistry.

9 **The following dimensions are of a nano ceramic particle :**

- **320 nm** • **135 nm** • **40 nm**

This particle is a ....

(a) one-dimensional nano substance.

(b) two-dimensional nano substance.

(c) three-dimensional nano substance.

(d) multi-walled substance.

10 **A meal includes 19 g of protein, 19 g of carbohydrates and 10 g of fats, this meal provides a person with 240 kcal, so if you know that each 1 g of fats burns releasing 9 kcal**
What is the percentage of energy resulting from the fats in this meal ?

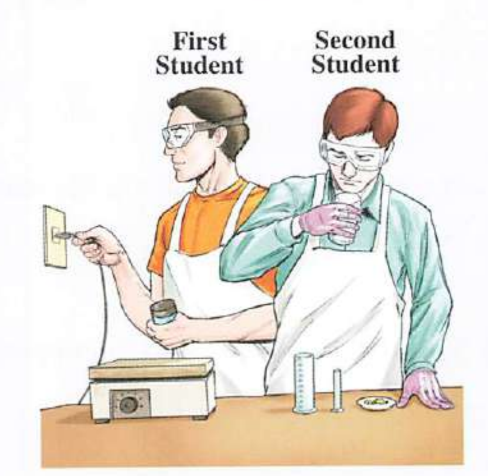
(a) 30%

(b) 34%

(c) 37.5%

(d) 42%

11 The opposite figure shows two students in chemistry lab, each of them did a mistake which violates the safety and security measures in the laboratories, **identify the mistake of each of them.**



- **The first student's mistake :**

....

....

- **The second student's mistake :**

....

....

12 The opposite figure represents a section in earth rocks, the rocks (V) are layers of limestone $CaCO_3$, they are formed of tiny crystalline particles whose volume starts from ($0.001\ m^3$) :

(1) What is the kind of integration between sciences in the previous paragraph ?

....

(2) Calculate the smallest volume of limestone crystals in nano scale.

....

....

....

.... 2 marks

13 The opposite figure represents the correct way to estimate the volume of a liquid in one of the measuring tools in lab :

(1) What is the volume of the liquid ?

....

(2) What is the name of this tool ? **Explain.**

....

....

....

....

.... 2 marks

14 **Why** are carbon nanotubes better than any other metal in manufacturing planes chassis ?

....

....

....

....

....

.... 1 mark

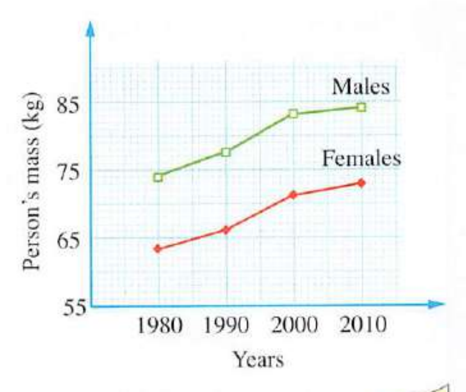
15. The opposite graph represents the change in the masses of the bodies of the youth (males and females) by time.

Suggest one technological reason to explain the change.

....

....

....



.... 1 mark

16. The opposite figure represents what happens to the particles of dust which cover a glass surface painted with an invisible substance when water falls on it.

What is the type of this invisible (transparent) substance, and what is the property which characterizes this substance ?

....

....

.... 1 mark

17. Viruses attack the intact cells through the protein which surrounds their membrane, in the same way the scientists try to destroy the cancer cells by synthesizing a protein that combines with the membrane of these cells, and then attacking them by nanounits carrying the proper chemical substances to destroy these cells alone without affecting the other intact cells.

What are the nanounits that can be used for this purpose ?

....

....

....

UNIT

2

Quantitative Chemistry

Chapter One — The Mole and the Chemical Equation.

The prelude Lesson		Writing the chemical formulas of the compounds.
Lesson 1	From Until	Chemical equation. Before the mole.
Lesson 2	From Until	The mole. Before the mole and Avogadro's number.
Lesson 3	From Until	The mole and Avogadro's number. The end of the chapter.

Chapter Two — Calculation of the Chemical Formula.

Exam model on the unit

Learning outcomes of unit two

By the end of this unit, the student will be able to :

- Express a chemical reaction using a balanced symbolical equation.
- Calculate the mass of the mole of a chemical compound by using the atomic mass.
- Mention the relationship between the mole and Avogadro's number.
- Identify the molar volume of gas at (STP).
- Calculate the number of moles of gas by using its volume and molar volume.
- Calculate the mass percentage of the components of a substance by using its chemical formula or with the experimental results.
- Deduce an empirical formula and a molecular formula of the compound by using the experimental results.
- Calculate the amounts of reactants and products in the balanced chemical equation.

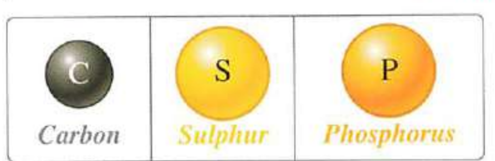
The included life topic : Rationalization of consumption.

Unit 2
Chapter One

The prelude Lesson

Writing the chemical formulas of the compounds

- Most of the elements of the periodic table exist in the form of monatomic molecules, **such as :**



- Only 7 of these elements exist in the form of diatomic molecules, **which are :**

H_2	N_2	O_2	F_2	Cl_2	Br_2	I_2
Hydrogen	*Nitrogen*	*Oxygen*	*Fluorine*	*Chlorine*	*Bromine*	*Iodine*

- The following table represents the difference between the symbols of the atoms, ions and the molecules of some elements and the chemical formulas of the molecules of some compounds :

Symbol or formula	Illustrative model	Refers to
C		Carbon atom.
O		Oxygen atom.
2O		Two uncombined oxygen atoms.
O^{2-}		Negative oxygen ion.
O_2		Oxygen molecule formed of the combination of two oxygen atoms.
CO		Carbon monoxide molecule formed of the combination of one carbon atom with one oxygen atom.

CO_2		Carbon dioxide **molecule** formed of the combination of one carbon atom with two oxygen atoms.
$2CO_2$		**Two** carbon dioxide **molecules.**

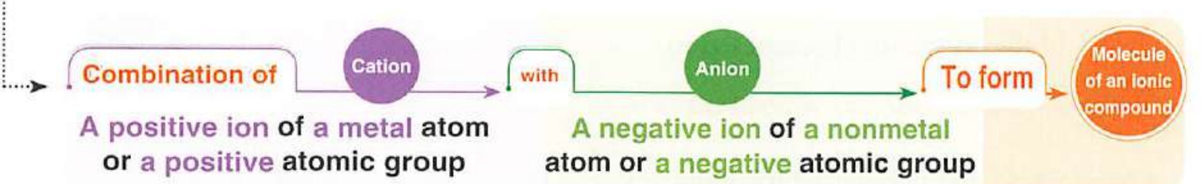
The chemical formulas of the compounds and their names

* This prelude (introduction) is about acquiring the skill of writing the chemical formulas of the compounds and their names, particularly :

1 Ionic compounds. **2 Covalent compounds.** **3 Acids.**

1 Ionic compounds

- **The ionic bond results from :**



*** Here are some examples of the cations and the anions forming ionic compounds :**

Cations (Metal ions)

Li^+	Lithium ion
Na^+	Sodium ion
K^+	Potassium ion
Ag^+	Silver ion
Mg^{2+}	Magnesium ion
Ca^{2+}	Calcium ion
Zn^{2+}	Zinc ion
Ba^{2+}	Barium ion
Al^{3+}	Aluminum ion
Fe^{2+}	Iron (II) [ferrous] ion
Fe^{3+}	Iron (III) [ferric] ion
Cu^+	Copper (I) [cuprous] ion
Cu^{2+}	Copper (II) [cupric] ion

Positive atomic group

NH_4^+	Ammonium group

Anions (Nonmetal ions)

Halides

F^-	Fluoride	O^{2-}	Oxide
Cl^-	Chloride	S^{2-}	Sulphide
Br^-	Bromide	N^{3-}	Nitride
I^-	Iodide	P^{3-}	Phosphide

Negative atomic groups

OH^-	Hydroxide	ClO_4^-	Perchlorate
NO_3^-	Nitrate	SO_4^{2-}	Sulphate
CH_3COO^-	Acetate	CO_3^{2-}	Carbonate
HCO_3^-	Bicarbonate	CrO_4^{2-}	Chromate
HSO_4^-	Bisulphate	$Cr_2O_7^{2-}$	Dichromate
NO_2^-	Nitrite	SO_3^{2-}	Sulphite
MnO_4^-	Permanganate	PO_4^{3-}	Phosphate

Naming the ionic compounds

* The name of any ionic compound consists of two syllables (sections), where the name of **the cation** is pronounced first followed by the name of **the anion.**

Cation	Anion
Sodium	chloride
Magnesium	nitrate

Writing the formulas of the ionic compounds

Applications

* The symbol of the cation is being written first, followed by the symbol of the anion, the valences are exchanged, so that the total charge of the compound becomes zero.

Magnesium nitride

$Mg^{2+}\ N^{3-}$ → Mg_3N_2

Aluminum oxide

$Al^{3+}\ O^{2-}$ → Al_2O_3

taking into consideration

- Not to write the number which indicates the monovalence.

Ammonium chloride

$NH_4^+\ Cl^- \Rightarrow NH_4Cl$

- Writing the atomic group between round brackets, then writing the valency at its bottom.

Iron (III) sulphate

$Fe^{3+}\ SO_4^{2-} \Rightarrow Fe_2(SO_4)_3$

- Reducing the numbers which indicate the valences to the simplest form.

Copper (II) sulphate

$Cu^{2+}\ SO_4^{2-} \Rightarrow CuSO_4$

Worked Examples

1 **Write the chemical formulas of the following manganese (Mn) oxides :**

(1) Manganese (II) oxide.

(2) Manganese (III) oxide.

(3) Manganese (IV) oxide (Manganese dioxide).

Answer:

$Mn^{2+}\ O^{2-} \Rightarrow MnO$

$Mn^{3+}\ O^{2-} \Rightarrow Mn_2O_3$

$Mn^{4+}\ O^{2-} \Rightarrow MnO_2$

2 **If the chemical formula of calcium pyrophosphate is $Ca_2P_2O_7$, so the chemical formula of iron (III) pyrophosphate is ....**

(a) $Fe_2(P_2O_7)_3$

(b) FeP_2O_4

(c) $Fe(P_2O_7)_3$

(d) $Fe_4(P_2O_7)_3$

Idea of answering :

$Ca_2P_2O_7$ molecule is electrically neutral, it consists of Ca^{2+} ion and $P_2O_7^{?}$ ion whose charge is unknown.

∵ Each molecule of $Ca_2P_2O_7$ contains two calcium ions, the charge of each of them is +2

∴ The charge of the two calcium ions = 2 × (+2) = +4

∴ The charge of P_2O_7 ion must be equal numerically to that of the two calcium ions and with an opposite sign, as the molecule is neutral.

∴ The charge of P_2O_7 ion = −4 ⇒ $(P_2O_7)^{4-}$

∴ The chemical formula of iron (III) pyrophosphate is :

$$Fe^{3+}\ P_2O_7^{4-} \Rightarrow Fe_4(P_2O_7)_3$$

Answer : The correct choice is (d)

Test Yourself

Write the chemical formulas of the following compounds :

(1) Silver chloride. ....

(2) Copper (II) nitrate. ....

(3) Ammonium carbonate. ....

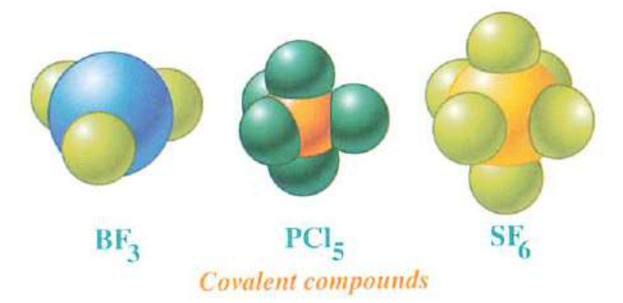
(4) Aluminum sulphate. ....

(5) Barium hydroxide. ....

(6) Sodium nitrite. ....

2 Covalent compounds

* Covalent compounds are formed of nonmetal elements by sharing electrons without gaining or losing.



Covalent compounds

Writing the chemical formulas of the covalent compounds which are formed from two elements

* The symbol of the firstly pronounced nonmetal is being written first, followed by the symbol of the second nonmetal preceded by the prefix which indicates the number of its repetitions in the formula of the compound.

Prefix	Mono	Di	Tri	Tetra	Penta	Hexa
Number of repetitions	1	2	3	4	5	6

- The digit (1) is not being written in any formula.

Applications

Carbon monoxide CO	Carbon dioxide CO_2	Boron trifluoride BF_3
Carbon tetrachloride CCl_4	Phosphorus pentabromide PBr_5	Sulphur hexafluoride SF_6

- There are some compounds which **do not obey this rule**, they usually have common names, **such as :**

Water H_2O	Ammonia NH_3	Phosphine PH_3	Methane CH_4

Test Yourself

Write the chemical formulas of the following compounds :

(1) Hydrogen iodide. ....

(2) Manganese dioxide. ....

(3) Sulphur trioxide. ....

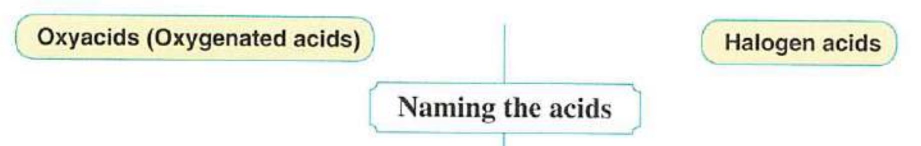
(4) Nitrogen trifluoride. ....

(5) Sulphur tetrachloride. ....

(6) Iodine heptafluoride. ....

3 Oxygenated acids and halogen acids

- All the chemical formulas of the acids **are similar** in that they all begin **with a positive hydrogen ion**, the acids can be classified into :



The name starts with **the name of the anion** followed **by the word acid, taking into consideration :**

Oxyacids (Oxygenated acids):

- Replacing the suffix (– ate) in the anion with the suffix (– ic).
- Replacing the suffix (– ite) in the anion with the suffix (– ous).

Halogen acids:

- The name of the anion is preceded by the word hydro.
- Replacing the suffix (– ide) with the suffix (– ic).

With exchanging the valences between the cation and the anion.

Writing the formulas of the acids

- The formula of any oxygenated acid begins with the hydrogen cation H^+, followed by the formula of the anion (the negative atomic group), excluding the hydroxide group (OH^-).
- The formula of any halogen acid begins with the hydrogen cation H^+, followed by the symbol of the anion (the halide).

Applications

Sulphuric acid

Hydrogen cation H^+ | Anion Sulphate (SO_4^{2-}) $\xrightarrow[+\text{ic}]{-\text{ate}}$ Sulphuric

→ H_2SO_4

Nitrous acid

Hydrogen cation H^+ | Anion Nitrite (NO_2^-) $\xrightarrow[+\text{ous}]{-\text{ite}}$ Nitrous

→ HNO_2

Hydrofluoric acid

Hydrogen cation H^+ | Anion Fluoride F^- $\xrightarrow[+\text{ic}]{-\text{ide}}$ Fluoric

→ HF

Hydrochloric acid

Hydrogen cation H^+ | Anion Chloride Cl^- $\xrightarrow[+\text{ic}]{-\text{ide}}$ Chloric

→ HCl

Test Yourself

Write the chemical formulas of the following compounds :

(1) Nitric acid. ....

(2) Sulphurous acid. ....

(3) Perchloric acid. ....

(4) Hydrobromic acid. ....

(5) Hydroiodic acid. ....

(6) Phosphoric acid. ....

Worked Example

All the chemical formulas of the compounds shown in the following table are correct, except ....

Choices	Compound	Chemical formula
(a)	Aluminum sulphate	$Al_2(SO_4)_3$
(b)	Carbonic acid	H_2CO_3
(c)	Iron (III) bromide	Fe_3Br
(d)	Phosphorus pentoxide	P_2O_5

Idea of answering :

∵ Aluminum sulphate contains Al^{3+} and $(SO_4)^{2-}$

∴ The chemical formula of aluminum sulphate is $Al^{3+}\ SO_4^{2-} \Rightarrow Al_2(SO_4)_3$

∴ The choice (a) is excluded.

∵ Carbonic acid contains H^+ and $(CO_3)^{2-}$

∴ The chemical formula of carbonic acid is $H^+\ CO_3^{2-} \Rightarrow H_2CO_3$

∴ The choice (b) is excluded.

∵ Iron (III) bromide contains Fe^{3+} and Br^-

∴ The chemical formula of iron (III) bromide is $Fe^{3+}\ Br^- \Rightarrow FeBr_3$

Answer : The correct choice is (c)

Answered

Multiple choice questions

1 P^{3-} ion is known as ....

(a) phosphide ion.
(b) phosphorus ion.
(c) phosphorus (III) ion.
(d) phosphine ion.

2 Which of the following choices is not correct ?

Choices	Ion	Formula
(a)	Sulphite	SO_3^{2-}
(b)	Phosphate	PO_4^{3-}
(c)	Hydride	OH^-
(d)	Nitrite	NO_2^-

3 The correct name of the compound $NaNO_3$ is ....

(a) trinitrogen oxide sodium.
(b) sodium nitrate.
(c) sodium nitrite.
(d) sodium nitride.

4 Ca^{2+} ions combine with PO_4^{3-} ions to form a salt with the chemical formula ....

(a) $CaPO_4$
(b) $Ca_2(PO_4)_3$
(c) $Ca(PO_4)_2$
(d) $Ca_3(PO_4)_2$

5 The chemical formula of magnesium chloride is ....

(a) $MgCl$
(b) $MgCl_2$
(c) Mg_2Cl
(d) Mg_2Cl_2

6 What is the chemical formula of iron (III) nitrate ?

(a) $Fe_2(NO_3)_3$
(b) $Fe(NO_3)_3$
(c) Fe_3NO_3
(d) $Fe_3(NO_3)_3$

7 **If the chemical formula of ammonium dichromate is $(NH_4)_2Cr_2O_7$, so the chemical formula of magnesium dichromate is ....**

(a) $MgCr_2O_7$
(b) $Mg_2Cr_2O_7$
(c) $Mg(Cr_2O_7)_2$
(d) $Mg_3(Cr_2O_7)_2$

8 **Which of the following names of compounds is not correct ?**

(a) Iron (II) chloride.
(b) Aluminum trioxide.
(c) Magnesium oxide.
(d) Phosphorus pentoxide.

9 **The correct name of LiCl is ....**

(a) lithium monochloride.
(b) lithium (I) chloride.
(c) lithium one chloride.
(d) lithium chloride.

10 **Which of the following compounds its chemical formula is not correct ?**

(a) Ammonium bromide NH_4Br
(b) Potassium carbonate K_2CO_3
(c) Barium phosphate $BaPO_4$
(d) Copper (I) chloride CuCl

11 **What is the formula of the compound which is produced from the reaction of calcium metal with sulphur nonmetal ?**

(a) Ca_3S
(b) CaS
(c) CaS_2
(d) Ca_3S_2

12 **(X) is a nonmetal which reacts with aluminum metal to form the compound AlX**

What is the name of the nonmetal (X) ?

(a) Oxygen.
(b) Fluorine.
(c) Chlorine.
(d) Nitrogen.

13 **The metal M hydroxide reacts with sulphuric acid according to the equation :**

$$M(OH)_{2(s)} + H_2SO_{4(aq)} \longrightarrow MSO_{4(aq)} + 2H_2O_{(l)}$$

Which of the following elements can be the metal M ?

(a) Sodium.
(b) Magnesium.
(c) Aluminum.
(d) Potassium.

14 **Which of the following acids its name is not correct ?**

(a) Sulphuric acid H_2SO_4

(b) Carbonic acid H_2CO_3

(c) Hydrochloride acid HCl

(d) Phosphoric acid H_3PO_4

Essay questions

15 **Write the chemical formulas of the following compounds :**

(1) Iron (III) hydroxide.

(2) Zinc carbonate.

(3) Lead (II) phosphate.

(4) Ammonium nitrate.

(5) Potassium bicarbonate.

(6) Potassium sulphite.

(7) Sulphur dioxide.

(8) Aluminum hydroxide.

(9) Sodium phosphate.

(10) Copper (II) chloride.

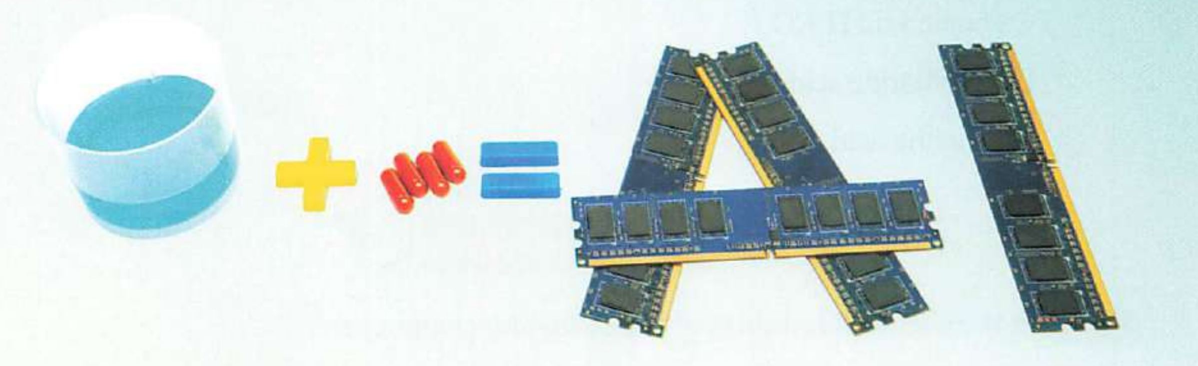
(11) Ammonium sulphate.

(12) Hydrogen sulphide.

(13) Carbon tetrafluoride.

(14) Barium sulphate.

(15) Silver chromate.



Chemical equation

The chemical reaction is represented by *a symbolic chemical equation*, **which is :**
A group of chemical symbols and formulas of the reactants and the products, which are connected by an arrow that determines the direction of the reaction and above which the reaction conditions are written.

- **The following table** represents signs which are included in any chemical equation and their indications :

Sign	Indication	Application
+	Separates each two reactants or products	$\underbrace{Mg + CuSO_4}_{\text{Reactants}} \longrightarrow \underbrace{MgSO_4 + Cu}_{\text{Products}}\downarrow$
$\longrightarrow$	An arrow separates the reactants from the products in the reactions (which proceed in only one direction)	
$\rightleftharpoons$	An arrow that separates the reactants from the products in the reversible reactions (which proceed in both directions forward and backward)	$N_2 + O_2 \rightleftharpoons 2NO$

- In the lower right-hand corner of **the element symbol** or **the chemical formula**, certain symbols are written to indicate the different physical states of each reactant and product, **illustrated in the following table :**

Symbol	(s)	(l)	(g)	(aq)	(v)
Indication *(Physical state)*	Solid	Liquid	Gas	Aqueous solution (Substance dissolved in water)	Vapour (solid or liquid vapourized by heat)
Examples	$Mg_{(s)}$ $AgCl_{(s)}$	$H_2O_{(l)}$ $Br_{2(l)}$	$O_{2(g)}$ $CO_{2(g)}$	$H_2SO_{4(aq)}$ $NaCl_{(aq)}$	$I_{2(v)}$ $H_2O_{(v)}$

- On the arrow which determines the reaction direction, reaction conditions are written (if there are conditions), **as those which are shown in the following table :**

Sign	Δ	P	**Symbols of some elements as :** Fe , Ni
Indication	**Heat**	**Pressure**	**Catalysts** to accelerate the reaction
Application	$N_{2(g)} + 3H_{2(g)} \xrightarrow[Fe]{\Delta / P} 2NH_{3(g)}$		

Worked Example

Sulphur reacts with nitric acid according to the equation :

$$S + 6HNO_3 \longrightarrow H_2SO_4 + 6NO_2 + 2H_2O$$

Which of the following represents the physical states of some reactants and products ?

(a) $H_2SO_{4(l)}$, $S_{(g)}$

(b) $H_2O_{(l)}$, $HNO_{3(aq)}$

(c) $HNO_{3(g)}$, $H_2O_{(v)}$

(d) $H_2SO_{4(aq)}$, $NO_{2(l)}$

Idea of answering :

∵ Sulphur S exists in the solid form (s) under normal conditions.

∴ The choice (a) is excluded.

∵ Nitric acid exists in its aqueous form (aq) or liquid form (ℓ), but it does not exist as a gas (g).

∴ The choice (c) is excluded.

∵ Nitrogen dioxide exists in its gaseous form (g).

∴ The choice (d) is excluded.

Answer : The correct choice is (b)

Balanced chemical equations

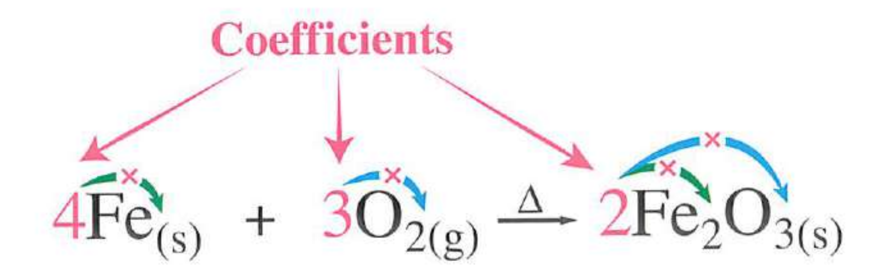
- The balanced chemical equation represents **the ratios** of the definite amounts by which the reactants react together to form the products.

In the balanced equation it is considered that :

1 Number of atoms of each element in the reactants equals the number of its atoms in the products to verify the law of conservation of matter.

This is fulfilled by writing numbers preceding the symbols of **the elements** and **the chemical formulas** of the compounds known as **the coefficients**, they represent the simplest ratio by which the reactants react together to form the products.

Application 1



Reactants

Fe	O
4 × 1 = 4	3 × 2 = 6

Products

Fe	O
2 × 2 = 4	2 × 3 = 6

$$2C_2H_{6(g)} + 7O_{2(g)} \xrightarrow{\Delta} 4CO_{2(g)} + 6H_2O_{(v)}$$

Reactants

C	H	O
4	12	14

Products

C	H	O
4	12	8 + 6 = 14

It is obvious in the previous balanced equation that each 2 units of C_2H_6 require 7 units of O_2 to be burnt completely,

to calculate the number of units of O_2 required to burn only one unit of C_2H_6,

the whole equation is being divided by 2 , **it is written as follows :**

$$C_2H_{6(g)} + \frac{7}{2}O_{2(g)} \xrightarrow{\Delta} 2CO_{2(g)} + 3H_2O_{(v)}$$

Reactants

C	H	O
2	6	7

Products

C	H	O
2	6	4 + 3 = 7

2 The coefficient (1) is not written in the balanced chemical equations.

Application

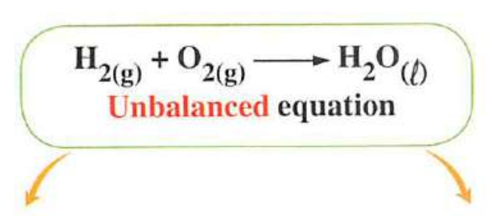
Reactants

Pb	O	H	N
3	4 + 12 = 16	4	4

Products

Pb	O	H	N
2 + 1 = 3	12 + 2 + 2 = 16	4	4

3 The chemical formula of any of the reactants or the products is not changed to balance the equation.



$H_{2(g)} + O_{2(g)} \longrightarrow H_2O_{2(l)}$

Wrong balancing

Despite that the number of the elements atoms are equal in both the reactants and the products, because the chemical formula of water (the product) is changed

$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$

Correct balancing

As the coefficients are changed to keep the number of elements atoms equal in both the reactants and the products without changing any chemical formula

Worked Examples

1 Which of the following represents the balanced equation of the reaction of aluminum with oxygen ?

(a) $2Al_{(s)} + 3O_{2(g)} \xrightarrow{\Delta} Al_2O_{3(s)}$

(b) $Al_{(s)} + O_{2(g)} \xrightarrow{\Delta} AlO_{2(s)}$

(c) $3Al_{(s)} + O_{2(g)} \xrightarrow{\Delta} Al_3O_{2(s)}$

(d) $4Al_{(s)} + 3O_{2(g)} \xrightarrow{\Delta} 2Al_2O_{3(s)}$

Idea of answering :

∵ Numbers of oxygen O atoms are not equal in both the reactants and the products.

∴ The choice (a) is excluded.

∵ Numbers of each of aluminum Al and oxygen O are equal in both the reactants and the products, but the chemical formulas of the reactants and the products must not be changed upon balancing the chemical equation, where aluminum reacts with oxygen yielding aluminum oxide Al_2O_3, not AlO_2 or Al_3O_2

∴ The choices (b) and (c) are excluded.

Answer : The correct choice is (d)

2 Write the balanced symbolic equation **which represents the reaction of nitrogen gas with hydrogen gas to form ammonia gas,** with writing **the physical states of the reactants and the products.**

Idea of answering :

1 Writing the initial (primary) equation, and checking if it is balanced.

$$N_{2(g)} + H_{2(g)} \longrightarrow NH_{3(g)}$$

Reactants

N	H
2	2
✗	✗

Products

N	H
1	3
✗	✗

The equation is unbalanced as the numbers of both N and H atoms are not equal in the reactants and in the products.

2 Balancing the atoms of nitrogen by multiplying the coefficient of $NH_3 \times 2$

$$N_{2(g)} + H_{2(g)} \longrightarrow 2NH_{3(g)}$$

Reactants

N	H
2	2
✓	✗

Products

N	H
2	6
✓	✗

The equation is still unbalanced, as the number of H atoms is not equal in the reactants and in the products.

3 Balancing the atoms of hydrogen by multiplying the coefficient of $H_2 \times 3$

$$N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$$

Reactants

N	H
2	6
✓	✓

Products

N	H
2	6
✓	✓

The equation is now balanced as the numbers of atoms of N and H are equal in both reactants and products.

Answer :

$$N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$$

3 Which of the following equations verifies the law of conservation of matter ?

(a) $H_2 + Cl_2 \longrightarrow HCl$

(b) $2H_2 + O_2 \longrightarrow H_2O$

(c) $Na_2 + Cl_2 \longrightarrow 2NaCl$

(d) $4P + 5O_2 \longrightarrow 2P_2O_5$

Idea of answering :

The law of conservation of matter is being verified in the chemical equation when the number of the atoms of each element in the reactants equals their number in the products.

∵ In the equation (a), the number of the atoms of each of H and Cl in the reactants does not equal their number in the products.

∴ The choice (a) is excluded.

∵ In the equation (b), the number of the atoms of each of H and O in the reactants does not equal their number in the products.

∴ The choice (b) is excluded.

∵ Sodium exists as a monatomic molecule in the normal conditions.

∴ The choice (c) is excluded.

∵ In the equation (d), the number of the atoms of each of P and O in the reactants equals their number in the products.

∴ Equation (d) verifies the law of conservation of matter.

Answer : The correct choice is (d)

Test Yourself

Rewrite the following word equation in the form of a balanced symbolic equation, with writing the physical state of each of the reactants and the products :

Sodium chloride solution + Silver nitrate solution ⟶ Sodium nitrate solution + Silver chloride salt

....

....

4 **The following equation is not balanced :** $K_3PO_4 + Ca(NO_3)_2 \longrightarrow Ca_3(PO_4)_2 + KNO_3$

Which of the following represents the correct balanced equation ?

(a) $K_6P_2O_8 + Ca_3N_6O_{18} \longrightarrow Ca_3P_2O_8 + K_6N_6O_{18}$

(b) $K_3PO_4 + Ca(NO_3)_2 \longrightarrow Ca_3(PO_4)_2 + 3KNO_3$

(c) $2K_3PO_4 + Ca(NO_3)_2 \longrightarrow Ca_3(PO_4)_2 + 6KNO_3$

(d) $2K_3PO_4 + 3Ca(NO_3)_2 \longrightarrow Ca_3(PO_4)_2 + 6KNO_3$

Idea of answering :

By comparing the numbers of atoms of each element in both sides of each equation in these 4 choices, it is found that equation (d) is balanced.

Reactants

K	P	O	Ca	N
6	2	26	3	6
✓	✓	✓	✓	✓

Products

K	P	O	Ca	N
6	2	26	3	6
✓	✓	✓	✓	✓

Answer : The correct choice is (d)

5 **In a chemical reaction, an oxygen atom combines with two potassium atoms forming K_2O compound.**

Conclude the coefficient of oxygen in the balanced symbolic equation of the reaction.

Idea of answering :

1 Initial unbalanced equation : $K_{(s)} + O_{2(g)} \longrightarrow K_2O_{(s)}$

2 Balancing potassium : $2K_{(s)} + O_{2(g)} \longrightarrow K_2O_{(s)}$

3 Balancing oxygen : $2K_{(s)} + O_{2(g)} \longrightarrow 2K_2O_{(s)}$

4 Rebalancing potassium : $4K_{(s)} + O_{2(g)} \longrightarrow 2K_2O_{(s)}$

Answer : The coefficient of oxygen in the balanced equation ⇒ 1

Test Yourself

The following equation is unbalanced :

$$Mg_3N_{2(s)} + H_2SO_{4(aq)} \longrightarrow MgSO_{4(aq)} + (NH_4)_2SO_{4(aq)}$$

What is the value of the coefficient of sulphuric acid after balancing the equation ?

(a) 1 (b) 3 (c) 4 (d) 7

Answer : The correct choice is ....

The equation of burning (the combustion of) the organic compounds

The organic compounds which are composed of :

The two elements (C and H) are known as hydrocarbons, **such as :**
Methane CH_4 , Propylene C_3H_6

Or

The elements (C , H and O) **such as :**
Methanol CH_3OH
Acetic acid CH_3COOH

On complete burning with oxygen, they give carbon dioxide gas and water vapour (or liquid water) according to the reaction conditions

The equation of burning glucose $C_6H_{12}O_6$

$$C_6H_{12}O_{6(s)} + 6O_{2(g)} \xrightarrow{\Delta} 6CO_{2(g)} + 6H_2O_{(v)}$$

Worked Example

Write the balanced symbolic equation which represents the reaction of the complete burning of acetaldehyde liquid CH_3CHO

Idea of answering :

1 Writing the initial symbolic equation with checking if it is balanced.

$$CH_3CHO_{(l)} + O_{2(g)} \xrightarrow{\Delta} CO_{2(g)} + H_2O_{(v)}$$

Reactants

C	H	O
2	4	3
✗	✗	✓

Products

C	H	O
1	2	3
✗	✗	✓

The equation is unbalanced.

2 Balancing carbon atoms by multiplying CO_2 coefficient × 2
and balancing hydrogen atoms by multiplying H_2O coefficient × 2

$$CH_3CHO_{(l)} + O_{2(g)} \xrightarrow{\Delta} 2CO_{2(g)} + 2H_2O_{(v)}$$

Reactants

C	H	O
2	4	3
✓	✓	✗

Products

C	H	O
2	4	6
✓	✓	✗

The equation is still unbalanced.

3 ∵ Number of oxygen atoms in the products is 6 and in acetaldehyde is 1

∴ Balancing oxygen atoms by multiplying O_2 coefficient $\times \frac{5}{2}$

$$CH_3CHO_{(l)} + \frac{5}{2} O_{2(g)} \xrightarrow{\Delta} 2CO_{2(g)} + 2H_2O_{(v)}$$

Reactants

C	H	O
2	4	6
✓	✓	✓

Products

C	H	O
2	4	6
✓	✓	✓

The equation is now balanced.

But the fraction coefficient of oxygen $\left(\frac{5}{2}\right)$ must be simplified by multiplying all the coefficients × 2

Answer : $2CH_3CHO_{(l)} + 5O_{2(g)} \xrightarrow{\Delta} 4CO_{2(g)} + 4H_2O_{(v)}$

Test Yourself

What is the coefficient of propene C_3H_6 in the balanced symbolic equation which represents its complete burning with oxygen ?

(a) 2 (b) 6 (c) 7 (d) 9

Idea of answering :

∵ Propene is an organic compound which burns with oxygen forming CO_2 gas and water vapour.

∴ This reaction is represented by the following equation :

$$C_3H_{6(g)} + \text{.......} O_{2(g)} \xrightarrow{\Delta} \text{...........}_{(g)} + \text{...........}_{(v)}$$

By multiplying the coefficients × .... to simplify the fraction.

$$\text{.......} C_3H_{6(g)} + \text{.......} O_{2(g)} \xrightarrow{\Delta} \text{...........}_{(g)} + \text{...........}_{(v)}$$

Answer : The correct choice is ....

Ionic equation

- Ionic equations can be used to represent some :

(1) **Physical processes, such as :**

Dissociation of the molecules of some ionic substances when they are :

- Thermally decomposed.
- Dissolved in water.

Dissolution of sodium chloride in water

The ionic equation which represents dissolving sodium chloride salt in water :

$$NaCl_{(s)} \xrightarrow{water} Na^+_{(aq)} + Cl^-_{(aq)}$$

Sodium chloride → Hydrated sodium ion + Hydrated chloride ion

(2) **Chemical reactions, such as :**

A Neutralization reactions

B Precipitation reactions

*** Before studying the ionic equations, it is necessary to know :**

1 The most famous acids and bases which ionize (dissociate) completely in water :

The most famous acids which ionize completely in water	The most famous bases which ionize completely in water
• Hydrochloric acid. $HCl_{(g)} \xrightarrow{water} H^+_{(aq)} + Cl^-_{(aq)}$	• Potassium hydroxide. $KOH_{(s)} \xrightarrow{water} K^+_{(aq)} + OH^-_{(aq)}$
• Nitric acid. $HNO_{3(l)} \xrightarrow{water} H^+_{(aq)} + NO^-_{3(aq)}$	• Sodium hydroxide. $NaOH_{(s)} \xrightarrow{water} Na^+_{(aq)} + OH^-_{(aq)}$
• Sulphuric acid. $H_2SO_{4(l)} \xrightarrow{water} 2H^+_{(aq)} + SO^{2-}_{4(aq)}$	• Barium hydroxide. $Ba(OH)_{2(s)} \xrightarrow{water} Ba^{2+}_{(aq)} + 2OH^-_{(aq)}$

2 The most famous salts that dissolve in water and those which do not dissolve in water :

The most famous salts which **dissolve** in water	The most famous salts which **do not dissolve** in water
• **All nitrate salts** dissolve in water. $KNO_{3(s)} \xrightarrow{water} K^+_{(aq)} + NO^-_{3(aq)}$	• **All phosphate salts** do not dissolve in water, **except :** $Na_3PO_{4(s)}$, $K_3PO_{4(s)}$, $(NH_4)_3PO_{4(s)}$
• **All bicarbonate salts** dissolve in water. $NaHCO_{3(s)} \xrightarrow{water} Na^+_{(aq)} + HCO^-_{3(aq)}$	• **All carbonate salts** do not dissolve in water, **except :** $Na_2CO_{3(s)}$, $K_2CO_{3(s)}$, $(NH_4)_2CO_{3(s)}$
• **All sulphate salts** dissolve in water, **except :** $Ag_2SO_{4(s)}$, $CaSO_{4(s)}$ $BaSO_{4(s)}$, $PbSO_{4(s)}$	• **All sulphite salts** do not dissolve in water, **except :** $Na_2SO_{3(s)}$, $K_2SO_{3(s)}$, $(NH_4)_2SO_{3(s)}$
• **All chloride salts** dissolve in water, **except :** $CuCl_{(s)}$, $PbCl_{2(s)}$ $AgCl_{(s)}$	• **All solid hydroxides** do not dissolve in water, **except :** $KOH_{(s)}$, $NaOH_{(s)}$ $NH_4OH_{(s)}$, $Ba(OH)_{2(s)}$ (The degree of solubility of $Ca(OH)_2$ is low)

A Ionic equation which represents a neutralization reaction

Steps of writing the ionic equation which represents neutralization reactions	Application (Reaction of sulphuric acid with sodium hydroxide solution to produce sodium sulphate and water)
(1) Writing the balanced symbolic equation of the chemical reaction.	$H_2SO_{4(aq)} + 2NaOH_{(aq)} \longrightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)}$
(2) Writing the reactants and the products in the form of ions, taking into consideration that water is a principal product and found in the form of molecules in the liquid state. (3) The ions which did not participate in the reaction are cancelled from both sides of the equation.	$2H^+_{(aq)} + SO^{2-}_{4(aq)} + 2Na^+_{(aq)} + 2OH^-_{(aq)} \longrightarrow 2Na^+_{(aq)} + SO^{2-}_{4(aq)} + 2H_2O_{(l)}$ *For illustration* Cancelled ions are called *spectator ions*
(4) Reducing the coefficients to the simplest form -when possible- to write the equation which shows only the reacting ions.	$2H^+_{(aq)} + 2OH^-_{(aq)} \longrightarrow 2H_2O_{(l)}$ $H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)}$ (This equation represents what is known as the net ionic equation for all neutralization reactions whatever the types of the strong acid and base are)

Worked Examples

1 The following 5 incomplete equations represent neutralization reactions of acids with bases in aqueous solutions :

(1) $HCl + NH_4OH \longrightarrow$

(2) $HNO_3 + Mg(OH)_2 \longrightarrow$

(3) $H_3PO_4 + Ba(OH)_2 \longrightarrow$

(4) $HCl + KOH \longrightarrow$

(5) $H_2CO_3 + LiOH \longrightarrow$

What is (are) the reaction(s) which is (are) represented by the ionic equation :

$H^+ + OH^- \longrightarrow H_2O$?

(a) Reaction (1) only.

(b) Reactions (1) , (4) and (5).

(c) Reactions (2) and (3) only.

(d) Reaction (4) only.

Idea of answering :

∵ NH_4OH is a weak incompletely ionized base, H_3PO_4 and H_2CO_3 are weak incompletely ionized acids.

∴ The choices (a), (b) and (c) are excluded.

Answer : The correct choice is (d)

2 **What is the net ionic equation which represents the reaction of acetic acid solution with potassium hydroxide solution ?**

(a) $CH_3COOH_{(aq)} + KOH_{(aq)} \longrightarrow CH_3COOK_{(aq)} + H^+_{(aq)} + OH^-_{(aq)}$

(b) $H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)}$

(c) $CH_3COOH_{(aq)} + OH^-_{(aq)} \longrightarrow CH_3COO^-_{(aq)} + H_2O_{(l)}$

(d) $CH_3COO^-_{(aq)} + KOH_{(aq)} \longrightarrow CH_3COOK_{(aq)} + H_2O_{(l)}$

Idea of answering :

∵ Potassium hydroxide KOH is a strong completely ionized base.

∴ The choices (a) and (d) are excluded.

∵ Acetic acid CH_3COOH is a weak incompletely ionized acid.

∴ The choice (b) is excluded.

Answer : The correct choice is (c)

B Ionic equation which represents a precepitation reaction

Steps of writing the ionic equation which represents precipitation reactions	Application (Reaction of silver nitrate solution with potassium chromate solution to form a red precipitate of silver chromate
(1) Writing the balanced symbolic equation of the chemical reaction.	$2AgNO_{3(aq)} + K_2CrO_{4(aq)} \longrightarrow 2KNO_{3(aq)} + Ag_2CrO_{4(s)}$
(2) Writing the reactants and the products in the form of ions, considering that the formed precipitate is insoluble in water and found in the solid state. (3) The ions which did not participate in the reaction are cancelled from both sides of the equation.	$2Ag^+_{(aq)} + \cancel{2NO^-_{3(aq)}} + \cancel{2K^+_{(aq)}} + CrO^{2-}_{4(aq)} \longrightarrow \cancel{2K^+_{(aq)}} + \cancel{2NO^-_{3(aq)}} + Ag_2CrO_{4(s)}$
(4) Writing the equation which shows only the reacting ions.	$2Ag^+_{(aq)} + CrO^{2-}_{4(aq)} \longrightarrow Ag_2CrO_{4(s)}$ The ionic equation of precipitation reactions differs from one reaction to another

*** It is noticed in the ionic equations of the neutralization reactions and the precipitation reactions that :**

- The summation of the positive charges equals the summation of the negative charges in each of the two sides of the equation.
- The number of atoms (ions) of the elements entering the reaction equals the number of those which are produced from the reaction.

Worked Examples

1 What is the net ionic equation which represents the reaction of calcium nitrate solution with sodium carbonate solution ?

(a) $Ca^{2+}_{(aq)} + CO^{2-}_{3(aq)} \longrightarrow CaCO_{3(s)}$

(b) $Na^{+}_{(aq)} + NO^{-}_{3(aq)} \longrightarrow NaNO_{3(s)}$

(c) $Ca(NO_3)_{2(aq)} + Na_2CO_{3(aq)} \longrightarrow 2NaNO_{3(s)} + CaCO_{3(s)}$

(d) $Ca(NO_3)_{2(aq)} + Na_2CO_{3(aq)} \longrightarrow 2NaNO_{3(aq)} + CaCO_{3(s)}$

Idea of answering :

Calcium nitrate solution reacts with sodium carbonate solution according to the equation :

$Ca(NO_3)_{2(aq)} + Na_2CO_{3(aq)} \longrightarrow 2NaNO_{3(aq)} + CaCO_{3(s)}$

This reaction is represented by the following complete ionic equation :

$Ca^{2+}_{(aq)} + \cancel{2NO^{-}_{3(aq)}} + \cancel{2Na^{+}_{(aq)}} + CO^{2-}_{3(aq)} \longrightarrow \cancel{2Na^{+}_{(aq)}} + \cancel{2NO^{-}_{3(aq)}} + CaCO_{3(s)}$

The net ionic equation after cancelling the spectator ions is :

$Ca^{2+}_{(aq)} + CO^{2-}_{3(aq)} \longrightarrow CaCO_{3(s)}$

Answer : The correct choice is (a)

---

2 What is the net ionic equation which represents the reaction of nitric acid solution with aluminum hydroxide ?

(a) $3H^{+}_{(aq)} + Al(OH)_{3(s)} \longrightarrow Al^{3+}_{(aq)} + 3H_2O_{(l)}$

(b) $3HNO_{3(aq)} + Al(OH)_{3(s)} \longrightarrow Al(NO_3)_{3(aq)} + 3H_2O_{(l)}$

(c) $HNO_{3(aq)} + OH^{-}_{(aq)} \longrightarrow NO^{-}_{3(aq)} + H_2O_{(l)}$

(d) $H^{+}_{(aq)} + OH^{-}_{(aq)} \longrightarrow H_2O_{(l)}$

Idea of answering :

∵ Aluminum hydroxide does not dissolve in water
(does not ionize giving $OH^{-}_{(aq)}$ ions).

∴ The choices ⓒ and ⓓ are excluded.

∵ Nitric acid is a strong acid which ionizes in water giving $H^{+}_{(aq)}$ ions.

∴ The choice ⓑ is excluded.

Answer : The correct choice is : ⓐ

---

3 What is the ionic equation which represents the formation of magnesium carbonate salt from the reaction of $MgCl_2$ and Na_2CO_3 solutions ?

ⓐ $Mg^{2+}_{(aq)} + CO^{2-}_{3(aq)} \longrightarrow MgCO_{3(aq)}$

ⓑ $Na_2CO_{3(aq)} + MgCl_{2(aq)} \longrightarrow 2Na^{+}_{(aq)} + 2Cl^{-}_{(aq)} + MgCO_{3(s)}$

ⓒ $Mg^{2+}_{(aq)} + CO^{2-}_{3(aq)} \longrightarrow MgCO_{3(s)}$

ⓓ $Na_2CO_{3(aq)} + MgCl_{2(aq)} \longrightarrow 2NaCl_{(aq)} + Mg^{2+}_{(s)} + CO^{2-}_{3(s)}$

Idea of answering :

∵ $MgCl_2$ salt and Na_2CO_3 salt both found in solutions in the form of ions, while magnesium carbonate salt is insoluble in water.

∴ This reaction can be represented by the following symbolic equation :

$$MgCl_{2(aq)} + Na_2CO_{3(aq)} \longrightarrow 2NaCl_{(aq)} + MgCO_{3(s)}$$

And it is represented by the following complete ionic equation :

$$Mg^{2+}_{(aq)} + \cancel{2Cl^{-}_{(aq)}} + \cancel{2Na^{+}_{(aq)}} + CO^{2-}_{3(aq)} \longrightarrow \cancel{2Na^{+}_{(aq)}} + \cancel{2Cl^{-}_{(aq)}} + MgCO_{3(s)}$$

The net ionic equation after cancelling the spectator ions is :

$$Mg^{2+}_{(aq)} + CO^{2-}_{3(aq)} \longrightarrow MgCO_{3(s)}$$

Answer : The correct choice is ⓒ

Preliminary questions to remember the main concepts of the lesson

Answer them yourself

1 Choose the correct answer :

(1) The abbreviation (g) is written down the right of the chemical formula of the compound in its ....

a. solid state. b. liquid state. c. gaseous state.

(2) What is the abbreviation which is written down the right of the chemical formula of sodium hydroxide aqueous solution ?

a. s b. ℓ c. aq d. g

(3) The chemical equation must be balanced to verify the law of ....

a. Avogadro. b. energy conservation.

c. mass conservation. d. fixed ratios.

(4) What is the equation which expresses correctly the physical states of both reactants and products in the reaction of magnesium combustion ?

a. $2Mg_{(s)} + O_{2(l)} \xrightarrow{\Delta} 2MgO_{(g)}$ b. $2Mg_{(s)} + O_{2(g)} \xrightarrow{\Delta} 2MgO_{(l)}$

c. $2Mg_{(s)} + O_{2(g)} \xrightarrow{\Delta} 2MgO_{(s)}$ d. $2Mg_{(s)} + O_{2(g)} \xrightarrow{\Delta} 2MgO_{(g)}$

(5) Which of the following represents the ionic equation of a precipitation process ?

a. $NaCl_{(s)} \longrightarrow Na^+_{(l)} + Cl^-_{(l)}$ b. $NaCl_{(s)} \longrightarrow Na^+_{(aq)} + Cl^-_{(aq)}$

c. $H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)}$ d. $Ag^+_{(aq)} + Cl^-_{(aq)} \longrightarrow AgCl_{(s)}$

(6) What are the ions which did not change in the following equation ?

$$Fe_{(s)} + CuSO_{4(aq)} \longrightarrow FeSO_{4(aq)} + Cu_{(s)}$$

a. $SO^{2-}_{4(aq)}$ b. $Cu_{(s)}$, $SO^{2-}_{4(aq)}$

c. $Fe_{(s)}$, $SO^{2-}_{4(aq)}$ d. $Fe_{(s)}$, $Cu_{(s)}$

2 Rewrite the following chemical equations after balancing each one :

(1) $N_{2(g)} + H_{2(g)} \longrightarrow NH_{3(g)}$

(2) $H_2SO_{4(aq)} + KOH_{(aq)} \longrightarrow K_2SO_{4(aq)} + H_2O_{(l)}$

(3) $Al_{(s)} + O_{2(g)} \xrightarrow{\Delta} Al_2O_{3(s)}$

(4) $Cu(NO_3)_{2(s)} \xrightarrow{\Delta} CuO_{(s)} + NO_{2(g)} + O_{2(g)}$

3 Write balanced symbolic equations to represent the following reactions, indicating the physical states of both reactants and products :

(1) Iron + Chlorine gas ⟶ Iron (III) chloride salt

(2) The reaction of barium chloride solution with magnesium sulphate solution to from magnesium chloride solution and barium sulphate salt.

4 Write the balanced ionic equations to represent the following reactions :

(1) The dissolution of magnesium chloride salt in water.

(2) Nitric acid + Potassium hydroxide solution ⟶ Potassium nitrate solution + Water

(3) The neutralization of sulphuric acid with barium hydroxide.

(4) The reaction of silver nitrate and sodium chloride solutions to form sodium nitrate solution and silver chloride precipitate.

Steady

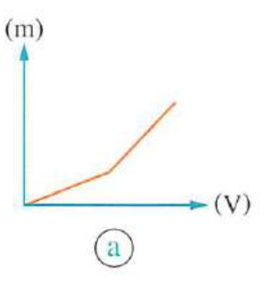
Open book questions

Answered

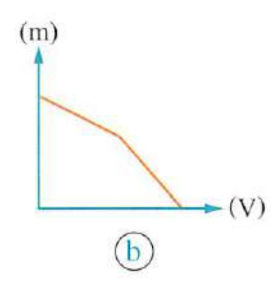
Multiple choice questions

Balanced chemical equations

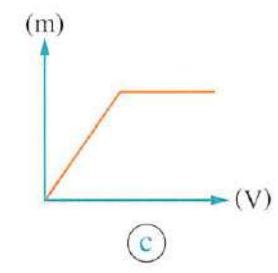
1 On adding drops of NaOH solution to $AlCl_3$ solution,
this reaction occurs : $AlCl_{3(aq)} + 3NaOH_{(aq)} \longrightarrow 3NaCl_{(aq)} + Al(OH)_{3(s)}$
, and when more NaOH solution is added to the reaction container,
this reaction occurs : $Al(OH)_{3(s)} + NaOH_{(aq)} \longrightarrow NaAlO_{2(aq)} + 2H_2O_{(l)}$
Which of the following graphical figures represents the relation between the mass of the formed precipitate (m) and the added volume of NaOH solution (V) ?



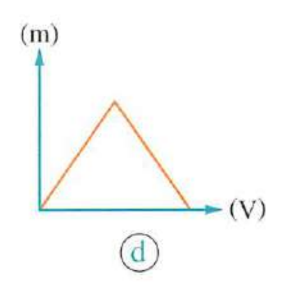
(a)



(b)



(c)



(d)

2 What is the equation which does not verify the law of conservation of mass ?

(a) $4Al + 3O_2 \xrightarrow{\Delta} 2Al_2O_3$

(b) $C_2H_6 + \frac{7}{2}O_2 \xrightarrow{\Delta} 2CO_2 + 3H_2O$

(c) $2KClO_3 \xrightarrow{\Delta} 2KCl + \frac{3}{2}O_2$

(d) $4P_4 + 5S_8 \xrightarrow{\Delta} 4P_4S_{10}$

3 This chemical equation is unbalanced : $As(OH)_3 + H_2SO_4 \longrightarrow As_2(SO_4)_3 + H_2O$
What is the coefficient of water after balancing the equation ?

(a) 2 (b) 4
(c) 6 (d) 8

4 The solid indium element reacts with chlorine gas forming $InCl_3$
What is the coefficient of $InCl_3$ in the balanced equation of the reaction ?

(a) 1 (b) 2
(c) 3 (d) 4

5 In the equation : $xP_4O_6 + H_2O \longrightarrow yH_3PO_3$

What is the value of the coefficient (y) when (x) = 2 ?

(a) 2 (b) 4

(c) 6 (d) 8

6 Sodium carbonate salt reacts with hydrochloric acid to form sodium chloride, carbon dioxide and water respectively.

What is the correct order of the coefficients of these substances in the balanced symbolic equation respectively ?

(a) 3, 6, 6, 3, 4 (b) 8, 6, 5, 10, 5

(c) 5, 10, 10, 5, 5 (d) 1, 2, 2, 1, 1

7 What is the summation of the coefficients in this equation after balancing ?

$$NaNH_2 + NaNO_3 \longrightarrow NaN_3 + NaOH + NH_3$$

(a) 9 (b) 8

(c) 7 (d) 6

The equation of burning (the combustion of) the organic compound

8 The compound $C_4H_8O_2$ burns completely in O_2 gas forming carbon dioxide gas and water vapour.

What is the coefficient of oxygen in the balanced equation of the combustion (burning) reaction ?

(a) 3 (b) 4

(c) 5 (d) 6

9 What is the coefficient of methanol $CH_3OH_{(\ell)}$ in the balanced equation of its complete combustion with oxygen ?

(a) $\frac{3}{2}$ (b) 2

(c) 3 (d) 4

10 The organic compounds burn yielding $CO_{2(g)}$ and $H_2O_{(v)}$

Which of the following compounds requires 3 mol of oxygen for the complete burning of 1 mol of it ?

(a) CH_3CHO (b) C_2H_5OH

(c) C_2H_6 (d) CH_3COOH

Ionic equation

11 **In terms of these equations :**

(1) $NaCl_{(s)} \xrightarrow{\Delta} Na^+_{(l)} + Cl^-_{(l)}$

(2) $NaCl_{(s)} \xrightarrow{water} Na^+_{(aq)} + Cl^-_{(aq)}$

Which of the following represents the two processes (1) and (2) ?

Choices	Process (1)	Process (2)
(a)	Neutralization	Precipitation
(b)	Melting	Dissolution
(c)	Dissolution	Melting
(d)	Precipitation	Neutralization

12 **Drops of sodium hydroxide are added to an amount of water in a tube.**
Which of the following does not exist in the tube ?

(a) OH^-
(b) Na^+
(c) NaOH
(d) Na^+ , OH^-

Ionic equation which represents a neutralization reaction

13 **What are the ions which are not written in the net ionic equation of the reaction of potassium hydroxide solution with hydrochloric acid ?**

(a) K^+ , H^+
(b) H^+ , OH^-
(c) K^+ , Cl^-
(d) H^+ , Cl^-

Ionic equation which represents a precipitation reaction

14 **Copper (II) sulphate solution reacts with sodium hydroxide solution forming a blue precipitate of copper (II) hydroxide.**
Which of the following equations represents the net ionic equation of this reaction ?

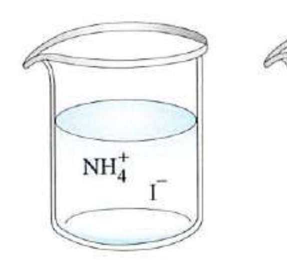
(a) $Cu^{2+}_{(aq)} + OH^-_{(aq)} \longrightarrow Cu(OH)_{2(s)}$

(b) $Cu^{2+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Cu(OH)_{2(s)}$

(c) $Cu^{+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Cu(OH)_{(s)}$

(d) $Cu^{2+}_{(s)} + 2OH^-_{(aq)} \longrightarrow Cu(OH)_{2(s)}$

15 The opposite figures show two beakers containing two different aqueous solutions. Which of the following equations is the net ionic equation which represents the reaction occurring between them ?



(a) $Ag^+_{(s)} + I^-_{(s)} \longrightarrow AgI_{(s)}$

(b) $Ag^+_{(aq)} + I^-_{(aq)} \longrightarrow AgI_{(s)}$

(c) $NH^+_{4(aq)} + NO^-_{3(aq)} \longrightarrow NH_4NO_{3(s)}$

(d) $NH^+_{4(aq)} + NO^-_{3(aq)} \longrightarrow NH_4NO_{3(aq)}$

16 The following equation represents the reactants in one of the chemical reactions,

$$2Na^+_{(aq)} + SO^{2-}_{4(aq)} + Ba^{2+}_{(aq)} + 2Cl^-_{(aq)} \longrightarrow$$

What are the products of the net ionic equation which represents this reaction ?

(a) $BaSO_{4(s)} + 2Na^+_{(aq)} + 2Cl^-_{(aq)}$

(b) $BaSO_{4(aq)}$

(c) $BaSO_{4(aq)} + 2Na^+_{(aq)} + 2Cl^-_{(aq)}$

(d) $BaSO_{4(s)}$

Essay questions

Balanced chemical equations

17 Balance the following equations :

(1) .... $KNO_3 \xrightarrow{\Delta}$ .... $KNO_2 +$ .... O_2

(2) .... $Na +$ .... $H_2O \longrightarrow$ .... $NaOH +$ .... H_2

(3) .... $Fe_3O_4 +$ .... $H_2 \longrightarrow$ .... $Fe +$ .... H_2O

(4) .... $MnO_2 +$ .... $HCl \longrightarrow$ .... $H_2O +$ .... $MnCl_2 +$ .... Cl_2

(5) .... $Pb(NO_3)_2 \xrightarrow{\Delta}$ .... $PbO +$ .... $NO_2 +$ .... O_2

(6) .... $C_2H_5OH +$ .... $O_2 \xrightarrow{\Delta}$ .... $CO_2 +$ .... H_2O

18 **Complete the following equations with what is suitable, with balancing them :**

(1) ___ HNO_3 + ___ $Al(OH)_3$ ⟶ ....

(2) ___ $FeCl_3$ + ___ $Pb(NO_3)_2$ ⟶ ....

(3) ___ KF + ___ $Sr(NO_3)_2$ ⟶ ....

19 **Write the balanced symbolic equations which represent the following reactions, with writing the physical states of both the reactants and the products :**

(1) Reaction of iron (III) oxide powder with carbon monoxide gas to form iron and carbon dioxide.

(2) Reaction of propane gas C_3H_8 with oxygen to form carbon dioxide gas and water vapour.

(3) Reaction of calcium phosphate salt with aqueous solution of sulphuric acid to form a precipitate of calcium sulphate and aqueous solution of phosphoric acid.

20 **Potassium can react with oxygen gas forming three different solid oxides, according to the reacting amount of each of oxygen gas and potassium, as follows :**

- **The first oxide :**
  In which each two atoms of potassium combine with one atom of oxygen.
- **The second oxide :**
  In which each two atoms of potassium combine with two atoms of oxygen.
- **The third oxide :**
  In which each one atom of potassium combines with two atoms of oxygen.

Deduce the coefficient of potassium in each of the three symbolic equations which represent the formation of these three oxides of potassium with oxygen gas.

Ionic equation which represents a precipitation reaction

21 **Barium sulphate salt can be precipitated by carrying out a reaction between an acid and a base :**

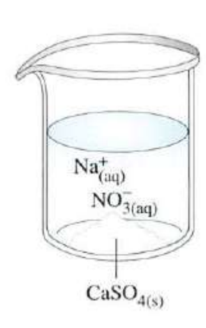
(1) Write the balanced symbolic equation which represents this reaction.

(2) Write the net ionic equation of this reaction.

22 **On mixing two solutions in a beaker, the illustrated substances in the opposite figure are formed :**

(1) Write the balanced symbolic equation which represents the reaction.

(2) Write the net ionic equation of this reaction.



New types of questions ? Answered

Choosing two out of five choices questions :

1 All the following equations are balanced, <u>except</u> ....

ⓐ $4Al + 3O_2 \longrightarrow 2Al_2O_3$

ⓑ $C_2H_6 + \frac{7}{2}O_2 \longrightarrow 2CO_2 + 3H_2O$

ⓒ $2KClO_3 \longrightarrow 2KCl + \frac{3}{2}O_2$

ⓓ $4P_4 + 5S_8 \longrightarrow 4P_4S_{10}$

ⓔ $As(OH)_3 + 3H_2SO_4 \longrightarrow As_2(SO_4)_3 + 6H_2O$

2 What are the reactions which can be represented by the following ionic equation : $H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)}$?

ⓐ $CH_3COOH_{(aq)} + KOH_{(aq)} \longrightarrow CH_3COOK_{(aq)} + H_2O_{(l)}$

ⓑ $HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$

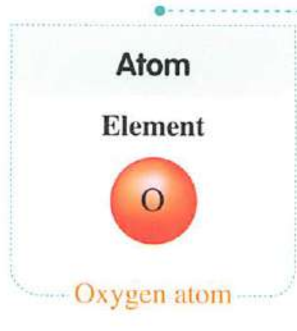
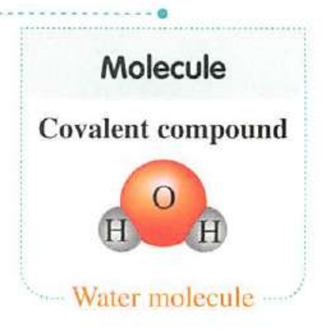
ⓒ $H_2CO_{3(aq)} + Mg(OH)_{2(aq)} \longrightarrow MgCO_{3(s)} + 2H_2O_{(l)}$

ⓓ $HCl_{(aq)} + NH_4OH_{(aq)} \longrightarrow NH_4Cl_{(aq)} + H_2O_{(l)}$

ⓔ $H_2SO_{4(aq)} + 2KOH_{(aq)} \longrightarrow K_2SO_{4(aq)} + 2H_2O_{(l)}$

* The building unit of the substance differs according to the form in which the substance exists, as shown in the following scheme :

The building unit of the substance may be

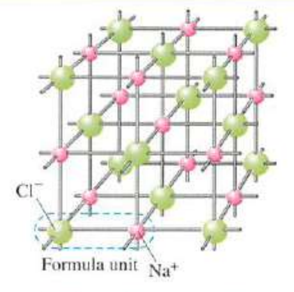
Atom	Formula unit	Molecule
Element	Ionic compound	Covalent compound
		
Oxygen atom	Formula unit of sodium nitrate	Water molecule

Remember

* **Atom** is the smallest building unit of matter which participates in chemical reactions.
* **Molecule** is the smallest fundamental part of matter which can exist solely, and retain the properties of this matter.

Note

* Ionic compounds exist in the form of a regular geometrical structure known as the crystal lattice, where each ion is surrounded by opposing ions (in terms of charge) from all directions.



Ball and stick model of the crystal lattice of sodium chloride

Worked Example

Which of the following equations represents the process of dissolving the table salt in water ?

(a) $NaCl_{(aq)} \xrightarrow{water} Na^+_{(aq)} + Cl^-_{(aq)}$

(b) $NaCl_{(s)} \xrightarrow{water} Na^+_{(s)} + Cl^-_{(s)}$

(c) $NaCl_{(s)} \xrightarrow{water} Na^+_{(aq)} + Cl^-_{(aq)}$

(d) $NaCl_{(aq)} \xrightarrow{water} Na^+_{(s)} + Cl^-_{(g)}$

Idea of answering :

∵ The ionic compounds such as table salt are found in form of solid crystals.

∴ The choices (a) and (d) are excluded.

∵ The crystal lattice of sodium chloride salt dissociates in water into $Na^+_{(aq)}$ and $Cl^-_{(aq)}$ ions.

∴ The equation which represents the dissolution of the table salt in water is

$NaCl_{(s)} \xrightarrow{water} Na^+_{(aq)} + Cl^-_{(aq)}$

Answer : The correct choice is (c)

* It is difficult practically to deal with the atom, the molecule or the formula unit in chemical calculations, **as** they are extremely small particles where their dimensions are estimated in nano scale.

The mole

* It represents the amounts of chemical substances in the international system of units (SI), where **it** is equivalent to the amount of a substance which contains the same number of units (atoms, ions, molecules or formula units) that exist in 12 g of carbon-12 ($^{12}_{6}C$).

A mole of carbon

Worked Examples

1 **A mole of sodium sulphite is similar to a mole of sodium sulphate in all of the following, except ....**

(a) number of moles of Na atoms.

(b) number of moles of S atoms.

(c) number of moles of O atoms.

(d) number of moles of ions in the aqueous solution.

Idea of answering :

The following table shows the number of moles of each of the atoms and the ions in one mole of each of the two compounds :

	Na_2SO_3	Na_2SO_4
Number of moles of Na atoms	2 mol	2 mol
Number of moles of S atoms	1 mol	1 mol
Number of moles of O atoms	3 mol	4 mol
Number of moles of the ions in the aqueous solution	3 mol	3 mol

Answer : The correct choice is (c)

2 **Which of the following shows the number of moles of each of magnesium chloride formula units, and sulphate anions in a mixture of magnesium chloride and magnesium sulphate which contains 4 mol Cl^- and 3 mol Mg^{2+} ?**

Choices	Number of moles of magnesium chloride formula units	Number of moles of sulphate anions
(a)	1 mol	1 mol
(b)	2 mol	1 mol
(c)	2 mol	3 mol
(d)	3 mol	4 mol

Idea of answering :

$\because$ The mixture consists of :

- Magnesium chloride $MgCl_2$ which dissociates in water according to the equation :

$$MgCl_{2(s)} \xrightarrow{\text{water}} Mg^{2+}_{(aq)} + 2Cl^-_{(aq)} \quad \text{....(1)}$$

- Magnesium sulphate $MgSO_4$ which dissociates in water according to the equation :

$$MgSO_{4(s)} \xrightarrow{\text{water}} Mg^{2+}_{(aq)} + SO^{2-}_{4(aq)} \quad \text{....(2)}$$

$\because$ The mixture contains 4 mol of Cl^- ions.

$\therefore$ The coefficients of the equation (1) are multiplied × 2

$$2MgCl_{2(s)} \xrightarrow{\text{water}} 2Mg^{2+}_{(aq)} + 4Cl^-_{(aq)} \quad \text{....(3)}$$

By addition of the equations (2) and (3) , it is found that :

$$2MgCl_{2(s)} + MgSO_{4\,(s)} \xrightarrow{\text{water}} 3Mg^{2+}_{(aq)} + 4Cl^-_{(aq)} + SO^{2-}_{4(aq)}$$

$\therefore$ Number of moles of formula units of magnesium chloride in the mixture = 2 mol

, number of moles of sulphate anions in the mixture = 1 mol

Answer : The correct choice is (b)

Test Yourself

What is the number of the moles of magnesium phosphate $Mg_3(PO_4)_2$ which contains 0.25 mol of oxygen atoms ?

(a) 1.25×10^{-2} mol
(b) 2×10^{-2} mol
(c) 2.5×10^{-2} mol
(d) 3.125×10^{-2} mol

Idea of answering :

$Mg_3(PO_4)_2$	$\xrightarrow{\text{contains}}$	.... O
1 mol		.... mol
? mol		0.25 mol

$\therefore$ Number of $Mg_3(PO_4)_2$ moles = ... = ... mol

Answer : The correct choice is ....

Molar mass

- The mass of one atom is called atomic mass, which is a very small amount, it is estimated in a unit known as atomic mass unit **amu** which can be shortened to **u**
- When the atomic mass of an element is estimated in grams, it is called the molar mass of atom, it is estimated in (g/mol)

as shown in the examples illustrated in the following table :

Element	Hydrogen H	Carbon C	Nitrogen N	Oxygen O	Sodium Na	Sulphur S
Atomic mass	1 u	12 u	14 u	16 u	23 u	32 u
Molar mass of atom	1 g/mol	12 g/mol	14 g/mol	16 g/mol	23 g/mol	32 g/mol

- The sum of gram atomic masses of the atoms that compose the molecule is known as gram molecular mass (g), or the molar mass (g/mol).

Application

The molar mass of hydrated copper sulphate crystals $CuSO_4.5H_2O$

[Cu = 63.5 , S = 32 , O = 16 , H = 1]

$$CuSO_4.5H_2O$$

$$Cu + S + (4 \times O) + (5 \times 2 \times H) + (5 \times O)$$

$$(63.5) + (32) + (4 \times 16) + (5 \times 2 \times 1) + (5 \times 16)$$

$$63.5 + 32 + 64 + 10 + 80 = 249.5 \text{ g/mol}$$

Worked Example

Calculate the molar mass of each of :

C = 12
H = 1
O = 16

(1) Methanol CH_3OH

(2) Sucrose $C_{12}H_{22}O_{11}$

Answer :

(1) Molar mass of methanol $CH_3OH = 12 + (4 \times 1) + 16 =$ **32 g/mol**

(2) Molar mass of sucrose $C_{12}H_{22}O_{11} = (12 \times 12) + (22 \times 1) + (11 \times 16) =$ **342 g/mol**

Molar masses of the elements with diatomic molecules

- **The molar mass** of a diatomic molecule of an element equals **double** its atomic molar mass, **as in the following table :**

Element	Hydrogen	Nitrogen	Oxygen	Fluorine	Chlorine	Bromine	Iodine
Molar mass of atom	H 1 g/mol	N 14 g/mol	O 16 g/mol	F 19 g/mol	Cl 35.5 g/mol	Br 80 g/mol	I 127 g/mol
Molar mass of molecule	H_2 2 × 1 = 2 g/mol	N_2 2 × 14 = 28 g/mol	O_2 2 × 16 = 32 g/mol	F_2 2 × 19 = 38 g/mol	Cl_2 2 × 35.5 = 71 g/mol	Br_2 2 × 80 = 160 g/mol	I_2 2 × 127 = 254 g/mol

Worked Example

Which of the following masses of oxygen and hydrogen are equal ? [O = 16 , H = 1]

Choices	Oxygen	Hydrogen
(a)	1 mol of atoms	32 mol of molecules
(b)	1 mol of molecules	8 mol of atoms
(c)	1 mol of molecules	16 mol of atoms
(d)	1 mol of atoms	8 mol of molecules

Idea of answering :

∵ Mass of 1 mol of O atoms = 1 × 16 = 16 g

, mass of 32 mol of H_2 molecules = 32 × (2 × 1) = 64 g

∴ The choice (a) is excluded.

∵ Mass of 1 mol of O_2 molecules = 1 × (2 × 16) = 32 g

, mass of 8 mol of H atoms = 8 × 1 = 8 g

∴ The choice (b) is excluded.

∵ Mass of 1 mol of O_2 molecules = 1 × (2 × 16) = 32 g

, mass of 16 mol of H atoms = 16 × 1 = 16 g

∴ The choice (c) is excluded.

∵ Mass of 1 mol of O atoms = 1 × 16 = 16 g

, mass of 8 mol of H_2 molecules = 8 × (2 × 1) = 16 g

∴ Mass of 1 mol of O atoms = Mass of 8 mol of H_2 molecules.

Answer : The correct choice is (d)

The difference of the molar mass according to the physical state

- The molar masses of some molecules of some elements differ according to their physical states, due to the difference of their molecular structure.

Application **Molar masses of vapours of phosphorus and sulphur.**

Element	Phosphorus	Sulphur
Gram atomic mass	31 g	32 g
Building units	Each molecule consists of 4 atoms	Each molecule consists of 8 atoms
The molecule of the element in its vapour state	P_4 (4 atoms)	S_8 (8 atoms)
Gram molecular mass in the vapour state	$4 \times 31 =$ 124 g/mol	$8 \times 32 =$ 256 g/mol

Test Yourself

Which of the following moles of the molecules of the gases and vapours contains the least number of moles of atoms ?

(a) Sulphur vapours.
(b) Nitrogen gas.
(c) Bromine vapours.
(d) Helium gas.

Idea of answering :

The following table exhibits the formulas of the molecules of the substances mentioned in the four choices :

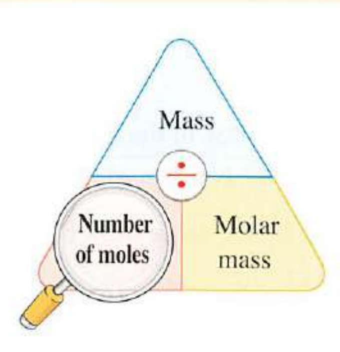
The substance	Sulphur vapours	Nitrogen gas	Bromine vapours	Helium gas
The formula of its molecule	S_8	N_2	Br_2	He

Answer : The correct choice is ....

Calculation of the number of moles

- **We can calculate the number of moles by using the following relation :**

$$\text{Number of moles (mol)} = \frac{\text{Mass of substance (g)}}{\text{Molar mass (mass of one mole) (g/mol)}}$$



Worked Examples

1 What is the number of moles of carbon atoms in a sample of it, its mass equals 144 g ? [C = 12]

(a) 6 mol

(b) 12 mol

(c) 18 mol

(d) 24 mol

Idea of answering :

$$\text{Number of moles of carbon atoms} = \frac{\text{Mass of carbon}}{\text{Molar mass of carbon}}$$

$$= \frac{144}{12} = 12 \text{ mol}$$

Answer : The correct choice is (b)

---

2 Calculate the number of moles of water found in 36 g of it. [H = 1 , O = 16]

Answer :

- The molar mass of $H_2O = (2 \times 1) + 16 = 18$ g/mol
- The number of moles of water $= \frac{\text{Mass of water}}{\text{Molar mass of water}}$

$$= \frac{36}{18} = \mathbf{2\ mol}$$

3 **Which of the following compounds the mass of 0.256 mol of it equals 12.928 g ?**

(a) C_2H_4O (b) CO_2 **[C = 12 , H = 1 , O = 16 , Cl = 35.5]**

(c) C_2H_6 (d) CH_3Cl

Idea of answering :

* The molar mass of the compound is calculated by the indication of the number of its moles and its mass.

- The molar mass of the compound = $\frac{\text{Mass of the compound}}{\text{Number of moles}} = \frac{12.928}{0.256} = 50.5$ g/mol
- The correct choice is that which has the same molar mass (50.5 g/mol).

∵ Molar mass of $C_2H_4O = (2 \times 12) + (4 \times 1) + 16 = 44$ g/mol

∴ The choice (a) is excluded.

∵ Molar mass of $CO_2 = 12 + (2 \times 16) = 44$ g/mol

∴ The choice (b) is excluded.

∵ Molar mass of $C_2H_6 = (2 \times 12) + (6 \times 1) = 30$ g/mol

∴ The choice (c) is excluded.

∵ Molar mass of $CH_3Cl = 12 + (3 \times 1) + 35.5 = 50.5$ g/mol

∴ The mass of 0.256 mol of CH_3Cl equals 12.928 g

Answer : The correct choice is (d)

---

4 **What is the mass of oxygen in a sample of $Na_2SO_4.10H_2O$ crystals its mass is 32.2 g ?**

(a) 50.79 g (b) 22.4 g **[Na_2SO_4 = 142 g/mol , H_2O = 18 g/mol , O = 16]**

(c) 16 g (d) 0.4 g

Idea of answering :

$$Na_2SO_4.10H_2O \xrightarrow{\text{contains}} 4O + 10O$$

1 mol → 14 mol

142 + (10 × 18) = 322 g/mol → 14 × 16 = 224 g

32.2 g → ? g

Mass of oxygen in the sample = $\frac{32.2 \times 224}{322} = 22.4$ g

Answer : The correct choice is (b)

5 If the mass of 0.5 mol of the compound WCl_2 equals 125 g :

(1) **Calculate the number of moles of chloride ions in a sample of this compound its mass = 250 g**

(2) **Calculate the molar mass of the compound WBr_2** [Cl = 35.5 , Br = 80]

Answer :

(1) 0.5 mol (WCl_2) $\xrightarrow{\text{its mass}}$ 125 g

? mol — 250 g

$\therefore$ Number of moles of $WCl_2 = \frac{0.5 \times 250}{125} = 1$ mol

WCl_2 $\xrightarrow{\text{contains}}$ $2Cl^-$

1 mol — 2 mol

$\therefore$ Number of moles of chloride ions $Cl^- =$ **2 mol**

(2) Mass of 2 mol of $Cl^- = 2 \times 35.5 = 71$ g

$\therefore$ Mass of W^{2+} ion = Mass of WCl_2 – Mass of 2 mol of $Cl^- = 250 - 71 = 179$ g

$\therefore$ Molar mass of $WBr_2 = 179 + (2 \times 80) =$ **339 g/mol**

Chemical calculations based on the balanced symbolic equation

1 (Mass – Mass) calculations

Worked Example

What is the mass of calcium oxide produced from the thermal decomposition of 10 g of calcium carbonate ? [Ca = 40 , C = 12 , O = 16]

ⓐ 178 g

ⓑ 56 g

ⓒ 17.8 g

ⓓ 5.6 g

Idea of answering :

Molar mass of $CaCO_3$ = 40 + 12 + (3 × 16) = 100 g/mol

Molar mass of CaO = 40 + 16 = 56 g/mol

$$CaCO_{3(s)} \xrightarrow{\Delta} CaO_{(s)} + CO_{2(g)}$$

100 g/mol	56 g/mol	
10 g	? g	

The produced mass of calcium oxide = $\frac{10 \times 56}{100}$ = 5.6 g

Answer : The correct choice is (d)

2 (Mole – Mass) calculations

Worked Example

What is the mass of NaCl produced from the reaction of 2 mol of NaOH with excess of HCl according to the equation : $NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(\ell)}$?

[Na = 23 , Cl = 35.5]

(a) 29.25 g
(b) 58.5 g
(c) 117 g
(d) 234 g

Molar mass of NaCl = 23 + 35.5 = 58.5 g/mol

Idea of answering ① :

$$NaOH_{(aq)} \xrightarrow{\text{produces}} NaCl_{(aq)}$$

1 mol	58.5 g
2 mol	? g

Mass of produced NaCl = $\frac{2 \times 58.5}{1}$

= 117 g

Idea of answering ② :

$$NaOH_{(aq)} \xrightarrow{\text{produces}} NaCl_{(aq)}$$

1 mol	1 mol
2 mol	? mol

Number of NaCl moles = 2 mol

Mass of produced NaCl

= Number of moles × Molar mass

= 2 × 58.5 = 117 g

Answer : The correct choice is (c)

3 (Mole – Mole) calculations

Worked Example

When modern cars collide with a wall, air bags are inflated instantaneously with nitrogen gas, as a result of these two following reactions :

* $2NaN_3 \longrightarrow 2Na + 3N_2$ .... (1)

* $10Na + 2KNO_3 \longrightarrow K_2O + 5Na_2O + N_2$ .... (2)

What is the total number of moles of nitrogen gas which are produced from the decomposition of 1 mol of sodium azide NaN_3 in excess of KNO_3 ?

(a) 1 mol (b) 1.6 mol (c) 2 mol (d) 6.1 mol

Idea of answering :

By multiplying the coefficients of the equation (1) × 5 , then adding it to the equation (2)

$$10NaN_3 \longrightarrow 10Na + 15N_2$$

$$10Na + 2KNO_3 \longrightarrow K_2O + 5Na_2O + N_2$$

By addition

$$10NaN_3 + 2KNO_3 \longrightarrow K_2O + 5Na_2O + 16N_2$$

$$10NaN_3 \xrightarrow{\text{produce}} 16N_2$$

10 mol 16 mol

1 mol ? mol

Total number of moles of nitrogen gas $= \frac{1 \times 16}{10} = 1.6$ mol

Answer : The correct choice is (b)

Test Yourself

Which of the following compounds when 1 mol of it is burnt, it produces 54 g of water vapour ? [H =1 , O = 16]

(a) C_4H_{10} (b) C_4H_9OH (c) C_2H_5OH (d) C_3H_8

Idea of answering :

- Calculation of the number of moles of $H_2O_{(v)}$ in 54 g of it.
- Number of H_2O moles $= \frac{\text{Mass of } H_2O}{\text{Molar mass of } H_2O} = \frac{54}{18} = 3$ mol
- Writing the balanced equation of burning each compound.
- The correct compound is the one which when 1 mol of it is burnt, it produces 3 mol of $H_2O_{(v)}$

Answer : The correct choice is ....

Preliminary questions to remember the main concepts of the lesson

Answer them yourself

1 Choose the correct answer :

(1) If the atomic mass of phosphorus is 31 u, the molar mass of phosphorus molecule in its vapor state is ....

a. 31 g/mol b. 62 g/mol c. 124 g/mol d. 155 g/mol

(2) The number of moles of potassium nitrate in 202 g of it is .... [K = 39 , O = 16 , N = 14]

a. 0.5 mol b. 1 mol c. 2 mol d. 2.5 mol

(3) What is the number of oxygen atoms in the formula unit of $Ca_3(PO_4)_2$?

a. 2 atoms. b. 4 atoms. c. 7 atoms. d. 8 atoms.

(4) The mass of 0.1 mol of sodium hydroxide equals .... [Na = 23 , O = 16 , H = 1]

a. 0.04 g b. 0.4 g c. 4 g d. 40 g

(5) CaO mass which is produced from the thermal decomposition of 50 g of $CaCO_3$ equals .... [Ca = 40 , O = 16 , C = 12]

a. 14 g b. 28 g c. 82 g d. 96 g

(6) Butane burns according to the equation :

$$2C_4H_{10(g)} + 13O_{2(g)} \xrightarrow{\Delta} 8CO_{2(g)} + 10H_2O_{(v)}$$

What is the number of moles of carbon dioxide gas produced from burning 3 mol of butane gas (C_4H_{10}) ?

a. 4 mol b. 8 mol c. 12 mol d. 24 mol

(7) When 80.5 g of sodium react with water, according to the following equation :

$$2Na_{(s)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}$$

The required number of water moles to complete this reaction is .... [Na = 23]

a. 2 mol b. 2.5 mol c. 3.5 mol d. 7 mol

2 Calculate the molar mass of :

(1) S_8 (2) CO_2 (3) NaCl (4) HNO_3

[S = 32 , C = 12 , O = 16 , Na = 23 , Cl = 35.5 , H = 1 , N = 14]

Steady

Open book questions

Answered

Multiple choice questions

The mole

1 **What is the number of the atoms in the formula unit of calcium bicarbonate $Ca(HCO_3)_2$?**

(a) 9 atoms.
(b) 10 atoms.
(c) 11 atoms.
(d) 12 atoms.

2 **A mole of potassium dichromate contains ....**

(a) 1 mol of K
(b) 4 mol of Cr
(c) 7 mol of O
(d) 1 mol of Cr

3 **Which of the following molecules, a mole of it contains the highest number of moles of the atoms ?**

(a) S_8
(b) $C_{10}H_8$
(c) $Al_2(SO_4)_3$
(d) Na_3PO_4

4 **In the balanced equation :**

$$Fe_3O_4 + X \longrightarrow FeCl_2 + 4H_2O + 2FeCl_3$$

What does (X) represent ?

(a) 4 mol of Cl_2
(b) 8 mol of Cl_2
(c) 8 mol of HCl
(d) 6 mol of HCl

5 **Propane C_3H_8 burns according to the equation :**

$$C_3H_{8(g)} + 5O_{2(g)} \xrightarrow{\Delta} 3CO_{2(g)} + 4H_2O_{(v)}$$

Which of the following represents the correct ratio between oxygen and propane gases as reactants ?

(a) $\frac{5\ g\ O_2}{1\ g\ C_3H_8}$
(b) $\frac{5\ mol\ O_2}{1\ mol\ C_3H_8}$
(c) $\frac{10\ g\ O_2}{11\ g\ C_3H_8}$
(d) $\frac{10\ mol\ O_2}{11\ mol\ C_3H_8}$

The molar mass

6 The ratio between the molar mass of the solid phosphorus to that of phosphorus in its vapour state is ....

(a) 1 : 4
(b) 2 : 1
(c) 3 : 1
(d) 4 : 1

7 What is the molar mass of barium sulphite ? [Ba = 137 , S = 32 , O = 16]

(a) 217 g/mol
(b) 233 g/mol
(c) 354 g/mol
(d) 514 g/mol

8 What is the mass of aluminum in 306 g of aluminum oxide Al_2O_3 ? [Al = 27 , O = 16]

(a) 81 g
(b) 162 g
(c) 200 g
(d) 243 g

9 If the molar mass of $M(OH)_3$ equals 78 g/mol, so the gram atomic mass of the element (M) equals .... [O = 16 , H = 1]

(a) 62 g
(b) 59 g
(c) 30 g
(d) 27 g

10 If the chemical formula of antimony oxide is Sb_2O_3 and that of sodium phosphate is Na_3PO_4 What is the molar mass of antimony phosphate ? [Sb = 121.8 , P = 31 , O = 16]

(a) 216.8 g/mol
(b) 338.6 g/mol
(c) 460.4 g/mol
(d) 528.6 g/mol

11
- Element (X) its gram atomic mass is 32 g/mol and its electronic configuration is (2 , 8 , 6).
- Element (Y) its gram atomic mass is 35.5 g/mol and its electronic configuration is (2 , 8 , 7).

What is the gram molecular mass of the compound produced from combining the atoms of the two elements (X) and (Y) ?

(a) 67 g/mol
(b) 99 g/mol
(c) 103 g/mol
(d) 134 g/mol

Calculations of the number of moles

12 **Which of these samples contains the highest number of moles of carbon atoms ?**

[C = 12 , H = 1 , O = 16]

(a) 29 g of C_4H_{10}

(b) 23 g of C_2H_5OH

(c) 22 g of CO_2

(d) 90 g of $C_6H_{12}O_6$

13 **What is the total number of moles of the ions found in 240 g of NH_4NO_3 ?**

[N = 14 , O = 16 , H = 1]

(a) 3 mol (b) 6 mol

(c) 9 mol (d) 27 mol

14 **Which of the following samples contains the same number of moles of $CaSO_4$ in 272 g of it ?**

[Ca = 40 , S = 32 , Cl = 35.5 , O = 16 , N = 14]

(a) 142 g of chlorine gas. (b) 40 g of oxygen gas.

(c) 35 g of nitrogen gas. (d) 2 g of hydrogen gas.

15 **What is the number of moles of an ions which combine with 138 g of the cations in sodium carbonate salt ?**

[Na = 23]

(a) 1.3 mol (b) 3 mol

(c) 6 mol (d) 23 mol

(Mass – Mass) calculations

16 **In the reaction :** $CH_{4(g)} + 4Cl_{2(g)} \longrightarrow CCl_{4(l)} + 4HCl_{(g)}$

What is the mass of CCl_4 which is produced from the reaction of 5.14 g of methane with excess of chlorine gas ?

[C = 12 , H = 1 , Cl = 35.5]

(a) 12.3 g (b) 0.54 g

(c) 791 g (d) 49.47 g

17 **What is the mass of the substance produced from the complete burning of a strip of magnesium whose mass equals 12 g in air ?**

[Mg = 24 , O = 16]

(a) 12 g (b) 20 g

(c) 40 g (d) 56 g

18 0.225 g of the metal (X) reacts with oxygen gas forming 0.425 g of the compound X_2O_3

What is the gram atomic mass of (X) ? [O = 16]

(a) 58 g/mol (b) 45 g/mol

(c) 25 g/mol (d) 27 g/mol

19 Two atoms of rubidium Rb combine with one atom of oxygen O to form rubidium oxide.

What is the mass of rubidium oxide which is produced from the reaction of 1.98 g of rubidium with excess of oxygen gas ? [Rb = 85.5 , O = 16]

(a) 1.81 g (b) 2.17 g

(c) 4.3 g (d) 8.6 g

(Mole – Mass) calculations

20 In the reaction : $3Mg + N_2 \xrightarrow{\Delta} Mg_3N_2$

What is the number of moles of nitrogen gas which react with 18 g of magnesium to form magnesium nitride compound ? [Mg = 24 , N = 14]

(a) 0.25 mol (b) 0.5 mol

(c) 1 mol (d) 2 mol

21 On passing water vapour over red hot coke, the following reaction occurs :

$$H_2O_{(v)} + C_{(s)} \xrightarrow{\Delta} CO_{(g)} + H_{2(g)}$$

What is the number of moles of the gases remaining in the reaction medium when 9 g of water vapour react with excess coke "assuming that the reaction container is closed" ? [H = 1 , O = 16 , C = 12]

(a) 0.5 mol (b) 1 mol

(c) 2 mol (d) 3 mol

22 Which of the following compounds 1 mol of it requires 96 g of oxygen gas to be burnt completely ? [O = 16]

(a) CH_3CHO (b) C_2H_5OH

(c) C_2H_6 (d) CH_3COOH

(Mole – Mole) calculations

23 **From the reaction equation :** $4NH_{3(g)} + 7O_{2(g)} \longrightarrow 4NO_{2(g)} + 6H_2O_{(v)}$

What is the least number of moles of oxygen required to oxidize 16 mol of ammonia gas ?

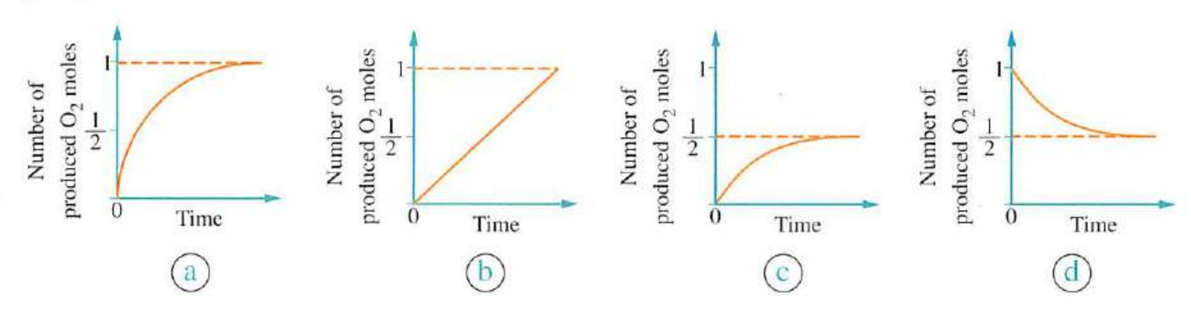
(a) 16 mol (b) 28 mol

(c) 64 mol (d) 80 mol

24 **Hydrogen peroxide decomposes according to the following equation :**

$$2H_2O_{2(\ell)} \longrightarrow 2H_2O_{(\ell)} + O_{2(g)}$$

Which of the following graphical figures represents the number of moles of oxygen gas produced at the end of the reaction ?



Calculation of the number of moles

25 **Calculate the molar mass** of lead element, knowing that the mass of 0.2 mol of it equals 41.4 g

26 **Calculate the mass** of oxygen in 25.99 g of potassium chromate compound.

[K = 39 , Cr = 52 , O = 16]

27 **Calculate the number of moles** of ammonium ions in a sample of ammonium carbonate salt its mass = 22.5 g [N = 14 , H = 1 , C = 12 , O = 16]

(Mass – Mass) calculations

28 **Calculate the mass** of carbon dioxide gas produced from burning 233.1 g of ethylene gas C_2H_4 in excess of oxygen gas, according to the following equation :

$$C_2H_{4(g)} + 3O_{2(g)} \xrightarrow{\Delta} 2CO_{2(g)} + 2H_2O_{(v)}$$

[C = 12 , H = 1 , O = 16]

29 **Sulphur is prepared from hydrogen sulphide in two steps, which are :**

1 $2H_2S + 3O_2 \longrightarrow 2SO_2 + 2H_2O$

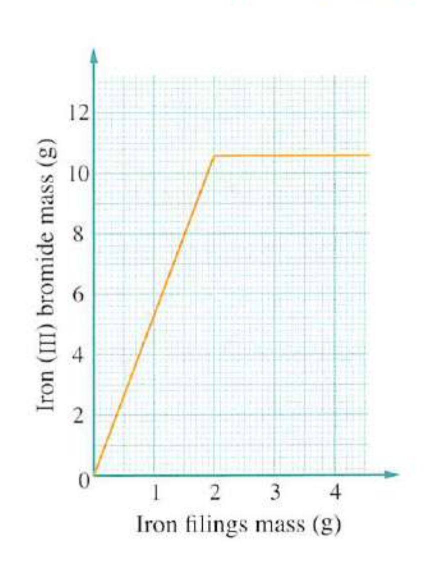
2 $SO_2 + 2H_2S \longrightarrow 3S + 2H_2O$

Calculate the mass of sulphur which is produced from the consumption of 21.5 g of oxygen. [S = 32 , O = 16]

30 The opposite graph represents the mass of iron (III) bromide produced from the reaction of iron filings with a definite mass of bromine at convenient conditions.

Calculate the gram atomic mass of bromine.

[Fe = 55.8]



(Mole – Mass) calculations

31 **Calculate the number of moles of iron (III) oxide Fe_2O_3** produced from heating 456 g of iron (II) sulphate $FeSO_4$ according to the equation : [Fe = 56 , S = 32 , O = 16]

$$2FeSO_4 \xrightarrow{\Delta} Fe_2O_3 + SO_2 + SO_3$$

(Mole – Mole) calculations

32 **Iron reacts with sulphur to form iron (III) sulphide, calculate the number of moles of :**

(1) Sulphur which are required to react with 6.2 mol of iron.

(2) Iron (III) sulphide produced from the reaction of 10.6 mol of iron with excess of sulphur.

New types of questions ? Answered

Choosing two out of five choices questions :

1 **1 mol of potassium carbonate differs from 1 mol of potassium bicarbonate in** ....

(a) the number of K atoms.

(b) the number of O atoms.

(c) the number of C atoms.

(d) the number of H atoms.

(e) the number of the anions.

2 **5.4 g of Mn are found in each of the following, except** .... [Mn = 55 , K = 39 , O = 16]

(a) 14 g of MnO

(b) 7.8 g of Mn_2O_3

(c) 8.6 g of MnO_2

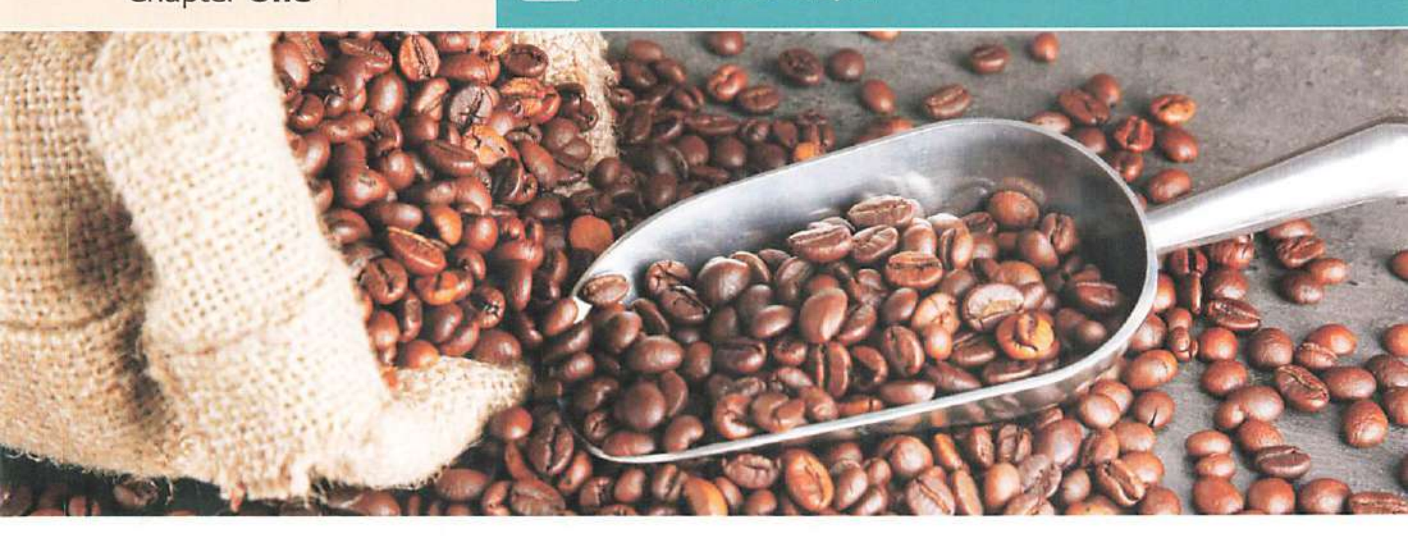
(d) 9.8 g of K_2MnO_4

(e) 15.7 g of $KMnO_4$

Lesson 3

From The mole and Avogadro's number

Until The end of the chapter



The mole and Avogadro's number

* The Italian scientist **Amedeo Avogadro** discovered that the number of particles (molecules , atoms , ions or formula units) that are found in one mole of any substance is a constant number, this number, later, was named after Avogadro's name (Avogadro's number) to honor him.

C atoms — 6.02×10^{23} atoms — Cu atoms

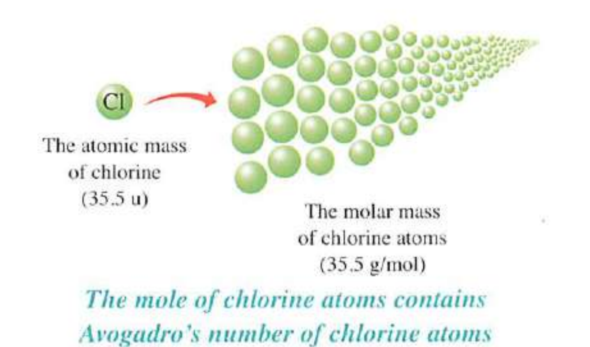
12 g — 63.5 g

1 mol of C — *1 mol of Cu*

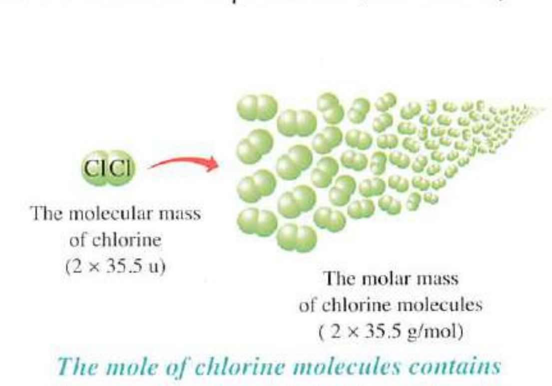
One mole of any substance contains Avogadro's number of particles

* Based on this, **Avogadro's number** can be defined as *the number of molecules, atoms, ions or formula units which are found in one mole of substance and it equals* 6.02×10^{23}

* In the light of the definition of Avogadro's number, **the mole** can be defined as *the amount of substance that contains Avogadro's number of particles (molecules, atoms, ions or formula units).*

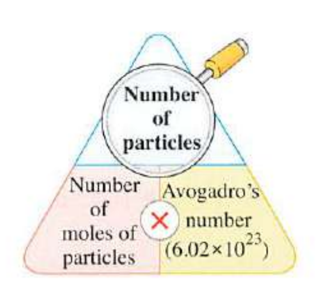


The mole of chlorine atoms contains Avogadro's number of chlorine atoms



The mole of chlorine molecules contains Avogadro's number of chlorine molecules

* Number of particles (molecules, atoms or ions) which are found in a definite amount of a substance (number of moles) can be calculated in terms of Avogadro's number,



using the relation :

Number of = Number of moles of × Avogadro's number

Molecules	Atoms	Ions		Molecules	Atoms	Ions		6.02×10^{23}

Worked Examples

1 What is the number of sodium ions in 0.2 mol of sodium sulphate ?

(a) 0.2 ion.

(b) 0.4 ion.

(c) 2.408×10^{23} ions.

(d) 1.204×10^{23} ions.

Idea of answering :

Na_2SO_4	$\xrightarrow{\text{contains}}$	$2Na^+ + SO_4^{2-}$
1 mol		2 mol
0.2 mol		? mol

Number of moles of sodium ions $Na^+ = 2 \times 0.2 = 0.4$ mol

Number of sodium ions Na^+ = Number of moles of ions × Avogadro's number

$$= 0.4 \times 6.02 \times 10^{23} = 2.408 \times 10^{23} \text{ ions}$$

Answer : The correct choice is (c)

2 **What is the number of molecules of sulphur dioxide found in a sample of it, its mass = 32 g ?** [S = 32 , O = 16]

(a) 3.01×10^{23} molecules.
(b) 0.5 molecule.
(c) 6.02×10^{23} molecules.
(d) 12.04×10^{23} molecules.

Idea of answering :

Molar mass of $SO_2 = 32 + (2 \times 16) = 64$ g/mol

Number of SO_2 moles $= \frac{\text{Mass of the substance}}{\text{Molar mass of this substance}} = \frac{32}{64} = 0.5$ mol

Number of SO_2 molecules = Number of moles of molecules × Avogadro's number

$$= 0.5 \times 6.02 \times 10^{23} = 3.01 \times 10^{23} \text{ molecules}$$

Answer : The correct choice is (a)

3 **Calculate the number of carbon atoms in 50 g of calcium carbonate.** [Ca = 40 , C = 12 , O = 16]

Answer :

Molar mass of $CaCO_3 = 40 + 12 + (3 \times 16) = 100$ g/mol

Number of moles of $CaCO_3 = \frac{CaCO_3 \text{ mass}}{CaCO_3 \text{ molar mass}} = \frac{50}{100} = 0.5$ mol

$CaCO_3$	$\xrightarrow{\text{contains}}$	C
1 mol		1 mol
0.5 mol		? mol

Number of moles of carbon atoms = 1 × 0.5 = 0.5 mol

Number of carbon atoms = Number of moles of carbon atoms × Avogadro's number

$$= 0.5 \times 6.02 \times 10^{23} = \mathbf{3.01 \times 10^{23} \text{ atoms}}$$

Another answer :

$CaCO_3$	$\xrightarrow{\text{contains}}$	C
1 mol		1 mol
100 g		6.02×10^{23} atoms
50 g		? atoms

Number of carbon atoms $= \frac{6.02 \times 10^{23} \times 50}{100} = \mathbf{3.01 \times 10^{23} \text{ atoms}}$

4 **A sample of a compound contains 5 g of hydrogen [H = 1], 35 g of nitrogen and 60 g of oxygen, calculate the number of hydrogen molecules in another sample of this compound, its mass equals 154.4 g**

Answer :

Mass of the first sample = 5 + 35 + 60 = 100 g

	Mass of the sample	→	Mass of hydrogen in the sample
First sample	100 g		5 g
Second sample	154.4 g		? g

Mass of hydrogen in the second sample $= \frac{5 \times 154.4}{100} = 7.72$ g

Number of hydrogen molecules moles $= \frac{\text{H mass}}{H_2 \text{ molar mass}}$

$$= \frac{7.72}{2} = 3.86 \text{ mol}$$

Number of hydrogen molecules = Number of moles of hydrogen molecules × Avogadro's number

$$= 3.86 \times 6.02 \times 10^{23} = 23.24 \times 10^{23} \text{ molecules}$$

Test Yourself

Calculate the number of atoms of the elements in 0.111 mol of $Fe(CO)_3(PH_3)_2$

Answer :

$Fe(CO)_3(PH_3)_2 \xrightarrow{\text{contains}}$ Fe + ... C + ... O + ... P + ... H

1 mol .... mol of atoms

0.111 mol ? mol of atoms

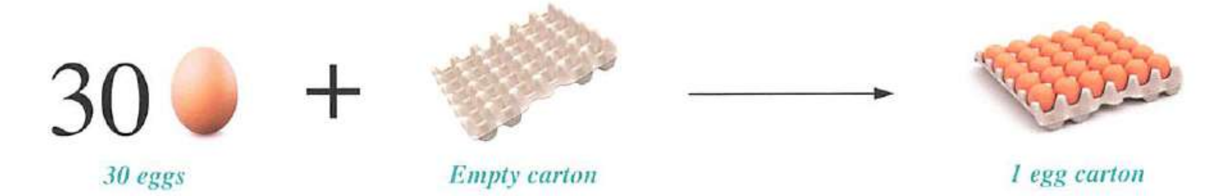
The number of moles of atoms of the elements = ...

The number of atoms of the elements = ... $= 1 \times 10^{24}$ atoms

The limiting reactant in the reaction

To clarify and simplify the concept of the limiting reactant, the following application will be studied :

* When you buy an egg carton, you will find that this one egg carton contains 30 eggs , this can be expressed by the following equation :



* Can you determine mathematically the number of egg cartons which can be prepared from :

- 150 eggs.
- 4 empty cartons.

Which of them its number exceeds the required number for the filling process , eggs or empty cartons ?

* This can be concluded through the previous equation, **as follows :**

Number of eggs +	Number of empty cartons ⟶	Number of egg cartons
30 eggs	1 empty carton	1 egg carton
150 eggs	4 empty cartons	? egg cartons

Number of egg cartons depending on :

Using all the eggs

30 eggs ⟶ 1 egg carton

150 eggs ⟶ ? egg cartons

$$\text{Number of egg cartons} = \frac{150 \times 1}{30}$$

= **5 egg cartons**

Using all empty cartons

1 empty carton ⟶ 1 egg carton

4 empty cartons ⟶ ? egg cartons

$$\text{Number of egg cartons} = \frac{4 \times 1}{1}$$

= **4 egg cartons**

* **Accordingly,** it is obvious that to use all the eggs in the filling, we need 5 empty cartons while the available empty cartons are only 4, therefore not all the eggs will be used but all the empty cartons will be used to produce egg cartons in a number that is lower than the number of the egg cartons which would be produced if we used all eggs, this is why we call the empty cartons "the limiting reactant" of the process of filling.

* Number of used eggs and the number of remaining eggs can be calculated, **as follows :**

$$1 \text{ empty carton} \xrightarrow{\text{filled with}} 30 \text{ eggs}$$
$$4 \text{ empty cartons} \xrightarrow{\text{filled with}} ? \text{ eggs}$$

Number of used eggs $= \frac{4 \times 30}{1} = 120$ eggs

The remaining (excess amount) of eggs after filling = 150 – 120 = 30 eggs

In the same manner :

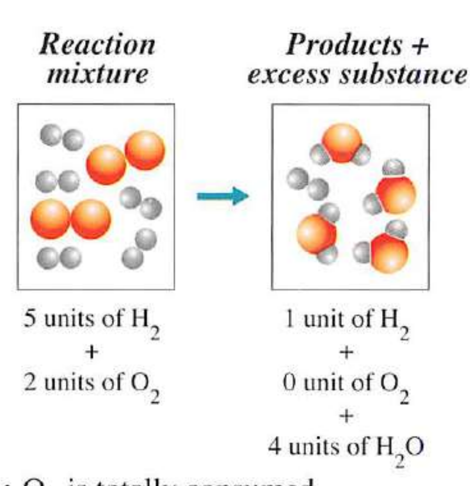
* Obtaining definite amounts of products through the chemical reactions requires using definite amounts of the reactants, but if the amount of one of the reactants exceeded the required amount for the reaction, this excess amount remains without being consumed in the reaction.

* *The substance which is totally consumed during the chemical reaction, and results in producing the lower amount of the product* **(limits the amount of the product)** is known as *the limiting reactant*.

Application

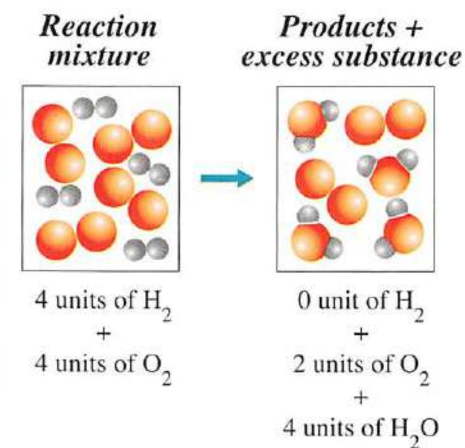
The reaction of formation of water.

$$2H_{2(g)} + O_{2(g)} \xrightarrow{\Delta} 2H_2O_{(v)}$$



∵ O_2 is totally consumed.

∴ **Oxygen O_2 is the limiting reactant.**



∵ H_2 is totally consumed.

∴ **Hydrogen H_2 is the limiting reactant.**

Worked Examples

1 Potassium hydroxide solution reacts with sulphuric acid according to the following equation :

$$2KOH_{(aq)} + H_2SO_{4(aq)} \longrightarrow K_2SO_{4(aq)} + 2H_2O_{(\ell)}$$

What is the limiting reactant, **when 4 mol of sulphuric acid are present with 3 mol of potassium hydroxide in the reaction medium ?**

Answer :

Number of produced moles of K_2SO_4 on consuming :

All $KOH_{(aq)}$

$$2KOH_{(aq)} \xrightarrow{\text{produce}} K_2SO_{4(aq)}$$

2 mol → 1 mol

3 mol → ? mol

Number of produced moles of $K_2SO_4 = \frac{1 \times 3}{2}$
$= 1.5$ mol

All $H_2SO_{4(aq)}$

$$H_2SO_{4(aq)} \xrightarrow{\text{produces}} K_2SO_{4(aq)}$$

1 mol → 1 mol

4 mol → ? mol

Number of produced moles of $K_2SO_4 = \frac{1 \times 4}{1}$
$= 4$ mol

∵ The lower number of moles of K_2SO_4 is produced as a result of consuming all KOH moles.

∴ **Potassium hydroxide KOH** is the limiting reactant in this reaction.

Another answer :

$$\text{The molar ratio of the compound} = \frac{\text{Number of used moles}}{\text{The coefficient of the compound in the balanced equation}}$$

Molar ratio of KOH $= \frac{3}{2} = 1.5$

Molar ratio of $H_2SO_4 = \frac{4}{1} = 4$

∵ The molar ratio of KOH is lower than that of H_2SO_4

∴ The limiting reactant in this reaction is **potassium hydroxide KOH**

---

2 7 g of iron react with 4 g of sulphur and produce 11 g of iron (II) sulphide.

What will remain in the reaction container when 7 g of iron are added to 7 g of sulphur ?

(a) 14 g of iron (II) sulphide only.

(b) 11 g of iron (II) sulphide, 3 g of iron.

(c) 11 g of iron (II) sulphide only.

(d) 11 g of iron (II) sulphide, 3 g of sulphur.

Idea of answering :

∵ Each 7 g of Fe react completely with 4 g of S to form 11 g of FeS

∴ 11 g of FeS will be formed with remaining of (7 – 4 = 3 g) of unreacted sulphur.

Answer : The correct choice is (d)

3 10 g of water vapour are passed on 16.8 g of iron which is heated till redness, according to the reaction :

$$3Fe_{(s)} + 4H_2O_{(v)} \xrightarrow{\Delta} Fe_3O_{4(s)} + 4H_{2(g)}$$

Which of the following represents properly this reaction ? [Fe = 55.9 , H = 1 , O = 16]

Choices	The limiting reactant in the reaction	The amount of the produced F_3O_4
(a)	H_2O	0.9 mol
(b)	Fe	0.9 mol
(c)	Fe	0.1 mol
(d)	H_2O	0.1 mol

Idea of answering :

- Molar mass of $H_2O = (1 \times 2) + 16 = 18$ g/mol
- Number of moles of $H_2O = \frac{10}{18} = 0.56$ mol
- Number of moles of Fe $= \frac{16.8}{55.9} = 0.3$ mol

Number of moles of Fe_3O_4 produced on consuming

All $Fe_{(s)}$

$3Fe_{(s)}$	$\longrightarrow$	$Fe_3O_{4(s)}$
3 mol		1 mol
0.3 mol		? mol

No. of produced Fe_3O_4 moles $= \frac{0.3}{3}$

$= 0.1$ mol

All $H_2O_{(v)}$

$4H_2O_{(v)}$	$\longrightarrow$	$Fe_3O_{4(s)}$
4 mol		1 mol
0.56 mol		? mol

No. of produced Fe_3O_4 moles $= \frac{0.56}{4}$

$= 0.14$ mol

∴ The lower number of Fe_3O_4 moles is produced on consuming all Fe moles.

∴ The limiting reactant in the reaction is Fe, and the produced amount of Fe_3O_4 is 0.1 mol

Answer : The correct choice is (c)

4 **Calcium oxide reacts with water according to the following equation :**

$$CaO_{(s)} + H_2O_{(l)} \longrightarrow Ca(OH)_{2(aq)}$$

Which of the following is the remaining unreacted mass of water, when 1.45 g of H_2O are added to 1.5 g of CaO ? [Ca = 40 , H = 1 , O = 16]

ⓐ 0.48 g ⓑ 0.97 g ⓒ 1.5 g ⓓ 1.8 g

Idea of answering :

$$CaO_{(s)} \xrightarrow{\text{reacts with}} H_2O_{(l)}$$

$40 + 16 = 56$ g $\qquad (2 \times 1) + 16 = 18$ g

1.5 g $\qquad$? g

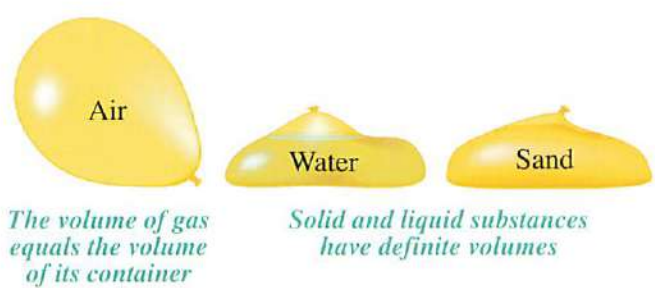
The reacted mass of water $= \frac{1.5 \times 18}{56} = 0.48$ g

The remaining unreacted mass of water $= 1.45 - 0.48 = 0.97$ g

Answer : The correct choice is ⓑ

The mole and the volume of gas

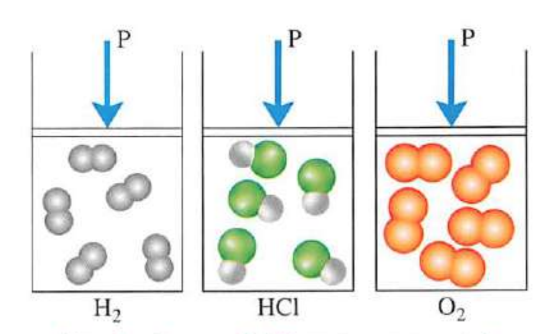
* Solid and liquid substances have definite and constant volumes, which can be measured by several methods, while the volumes of the gaseous substances equal the volumes of their containers.



The volume of gas equals the volume of its container

Solid and liquid substances have definite volumes

* The scientist Avogadro stated the relation between the volumes of gases and their number of molecules known as **Avogadro's postulate**, this postulate states that equal volumes of different gases - at the same conditions of temperature and pressure - contain equal numbers of molecules.



Equal volumes of different gases contain the same number of molecules at the same conditions of temperature and pressure

Worked Example

Which of the following is an application of Avogadro's postulate at the standard conditions ?

(a) 10 g of O_2 gas contain the same number of molecules found in 10 g of H_2 gas.

(b) 10 g of O_2 gas contain the same number of molecules found in 10 L of H_2 gas.

(c) 10 L of O_2 gas contain the same number of molecules found in 10 mol of H_2 gas.

(d) 10 L of O_2 gas contain the same number of molecules found in 10 L of H_2 gas.

Idea of answering :

∵ Equal volumes of different gases – at the same conditions of pressure and temperature – contain equal numbers of molecules according to Avogadro's postulate.

Answer : The correct choice is (d)

* **Afterwards, Avogadro discovered that**

at the standard conditions (at STP) :

- A mole of any gas occupies 22.4 L volume.
- A mole of any gas contains 6.02×10^{23} molecules.

Standard conditions STP

Standard Temperature and Pressure

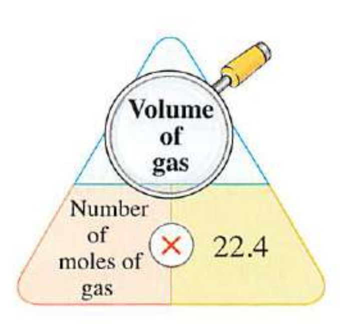
Which are :

- $0^\circ C$ temperature = 273 K
- 1 atm pressure = 760 mmHg

* **The relation between the number of moles**

of gas and its volume (at STP) can be expressed as follows :

The volume of gas (L) =
Number of moles of gas (mol) × 22.4 (L/mol)



- **The following table illustrates the relation between the number of moles of gas, its volume and its number of molecules and atoms (at STP) for different gases :**

Gas	He	O_2	CO_2	Ne	H_2
Given mass in grams	4 g	16 g	22 g	5 g	0.5 g
Molar mass	4 g/mol	32 g/mol	44 g/mol	20 g/mol	2 g/mol
Number of moles (n)	$\frac{4}{4} = 1$ mol	$\frac{16}{32} = 0.5$ mol	$\frac{22}{44} = 0.5$ mol	$\frac{5}{20} = 0.25$ mol	$\frac{0.5}{2} = 0.25$ mol
Volume (V) (at STP)	22.4 L	$0.5 \times 22.4 = 11.2$ L		$0.25 \times 22.4 = 5.6$ L	
Number of molecules	6.02×10^{23} molecules	$0.5 \times 6.02 \times 10^{23} = 3.01 \times 10^{23}$ molecules		$0.25 \times 6.02 \times 10^{23} = 1.505 \times 10^{23}$ molecules	
Number of atoms	6.02×10^{23} atoms	$0.5 \times 2 \times 6.02 \times 10^{23} = 6.02 \times 10^{23}$ atoms	$0.5 \times 3 \times 6.02 \times 10^{23} = 9.03 \times 10^{23}$ atoms	$0.25 \times 6.02 \times 10^{23} = 1.505 \times 10^{23}$ atoms	$0.25 \times 2 \times 6.02 \times 10^{23} = 3.01 \times 10^{23}$ atoms

Worked Examples

1 **What is the volume which is occupied by 39.2 g of nitrogen gas (at STP) ?** [N = 14]

(a) 16 L (b) 31.36 L

(c) 62.72 L (d) 1.6 L

Idea of answering :

Molar mass of N_2 gas $= 2 \times 14 = 28$ g/mol

Number of N_2 moles $= \frac{N_2 \text{ mass}}{N_2 \text{ molar mass}} = \frac{39.2}{28} = 1.4$ mol

Volume of N_2 gas = Number of moles $\times 22.4 = 1.4 \times 22.4 = 31.36$ L

Answer : The correct choice is (b)

2 **What is the mass of a sample of nitrous oxide gas N_2O which occupies 550 mL (at STP) ?** [N = 14 , O = 16]

(a) 1.08×10^3 g

(b) 0.025 g

(c) 5.68×10^{-4} g

(d) 1.1 g

Idea of answering :

Volume of N_2O gas $= \frac{550}{1000} = 0.55$ L

Number of moles of N_2O gas $= \frac{\text{Volume of gas}}{22.4}$

$= \frac{0.55}{22.4} = 0.025$ mol

Molar mass of N_2O gas $= (2 \times 14) + 16 = 44$ g/mol

Mass of N_2O gas = Number of moles × Molar mass

$= 0.025 \times 44 = 1.1$ g

Answer : The correct choice is (d)

---

3 **Calculate the volume of oxygen gas (at STP) which is required for burning 2.6 g of ethyne gas C_2H_2** [C = 12 , H = 1]

Answer :

Molar mass of C_2H_2 gas $= (2 \times 12) + (2 \times 1) = 26$ g/mol

Number of moles of C_2H_2 gas $= \frac{C_2H_2 \text{ mass}}{C_2H_2 \text{ molar mass}} = \frac{2.6}{26} = 0.1$ mol

$$2C_2H_{2(g)} + 5O_{2(g)} \xrightarrow{\Delta} 4CO_{2(g)} + 2H_2O_{(v)}$$

2 mol　　5 mol

0.1 mol　　? mol

Number of moles of O_2 gas $= \frac{0.1 \times 5}{2} = 0.25$ mol

Volume of O_2 gas = Number of moles × 22.4 = 0.25 × 22.4 = **5.6 L**

4 **Methane gas burns completely forming carbon dioxide gas and water vapour, according to the equation :**

$$CH_{4(g)} + 2O_{2(g)} \xrightarrow{\Delta} CO_{2(g)} + 2H_2O_{(v)}$$

Which of the following expresses the reactants and the products in this reaction (at STP) ?

(a) 1 mol of CH_4 gas contains Avogadro's number of atoms.

(b) 1 mol of methane gas occupies a volume equals 12 L

(c) The volume of the produced CO_2 gas equals double the volume of the consumed CH_4 gas.

(d) The complete burning of 1 mol of CH_4 gas results in producing 67.2 L of gases and vapours.

Idea of answering :

∵ Number of moles of the atoms in 1 mol of CH_4 = 5 mol

∴ Number of the atoms in 1 mol of CH_4 = 5 × Avogadro's number

(**i.e.** 1 mol of CH_4 contains 5 times as Avogadro's number of atoms)

∴ The choice (a) is excluded.

∵ 1 mol of any gas occupies 22.4 L (at STP).

∴ The choice (b) is excluded.

∵ Number of moles of the produced CO_2 gas equals that of the consumed CH_4 gas.

∴ The volume of CO_2 gas equals that of CH_4 gas (at STP).

∴ The choice (c) is excluded.

∵ 1 mol of CH_4 gas produces - on burning - 3 mol of gases and vapours.

∴ Volume of the produced gases and vapours (at STP) = 3 × 22.4

= 67.2 L

Answer : The correct choice is (d)

5 **Nitrogen gas reacts with oxygen gas according to the equation :**

$$N_{2(g)} + 2O_{2(g)} \longrightarrow 2NO_{2(g)}$$

What are the volumes of the gases which remain in the reaction vessel (at STP) after the end of the reaction on mixing 50 mL of nitrogen gas with 50 mL of oxygen gas ?

Choices	$N_{2(g)}$	$O_{2(g)}$	$NO_{2(g)}$
(a)	0	0	100 mL
(b)	0	25 mL	50 mL
(c)	25 mL	0	50 mL
(d)	25 mL	25 mL	50 mL

Idea of answering :

Volume of $NO_{2(g)}$ produced on consuming

All $N_{2(g)}$

$N_{2(g)}$ —produces→ $2NO_{2(g)}$

1 mol — 2 mol

(22.4×10^3) mL — $(2 \times 22.4 \times 10^3)$ mL

22400 mL — 44800 mL

50 mL — ? mL

Volume of the produced NO_2 gas

$$= \frac{50 \times 44800}{22400} = 100 \text{ mL}$$

All $O_{2(g)}$

$2O_{2(g)}$ —produce→ $2NO_{2(g)}$

2 mol — 2 mol

$(2 \times 22.4 \times 10^3)$ mL — $(2 \times 22.4 \times 10^3)$ mL

44800 mL — 44800 mL

50 mL — ? mL

Volume of the produced NO_2 gas

$$= \frac{50 \times 44800}{44800} = 50 \text{ mL}$$

∵ Lower volume of NO_2 is produced on consuming all O_2

∴ O_2 is the limiting reactant of this reaction.

∴ Volume of O_2 remaining in the reaction vessel = Zero

∴ The choices (b) and (d) are excluded.

∵ The produced volume of NO_2 gas = 50 mL

∴ The choice (a) is excluded.

Answer : The correct choice is (c)

Test Yourself

According to the reaction : $Zn_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$

What is the produced volume of hydrogen gas when 12.04×10^{23} atoms of zinc react with excess of the acid ?

(a) 22.4 L
(b) 44.8 L
(c) 11.35 L
(d) 68.1 L

Idea of answering :

....

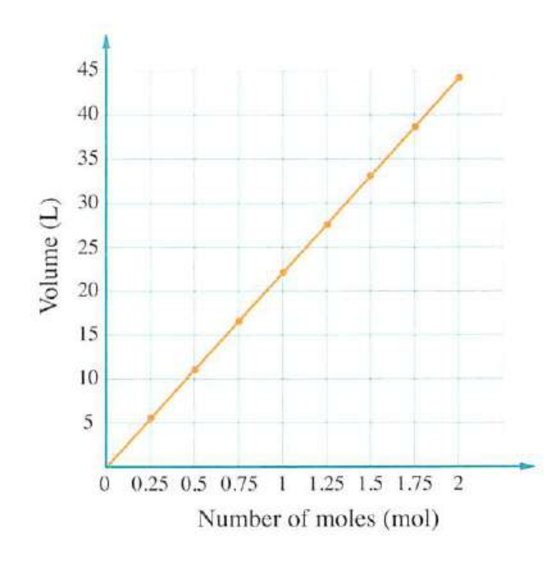
....

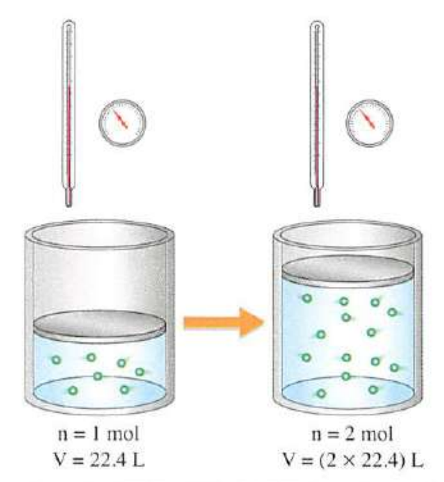
....

Answer :

The correct choice is ....

* The scientist **Avogadro** discovered the relation between the volume of gas and its number of moles, known as **Avogadro's law** which states that *the volume of gas is directly proportional to the number of its moles at constant temperature and pressure.*





The volume of gas is doubled by doubling its number of moles (n) at the same temperature and pressure

Worked Example

Two samples of oxygen and nitrogen gases have the same mass at the same conditions of pressure and temperature.

Which of the following is the ratio between $N_2 : O_2$ volumes ? [O = 16 , N = 14]

ⓐ $\frac{8}{7}$ ⓑ $\frac{5}{3}$ ⓒ $\frac{5}{6}$ ⓓ $\frac{2}{9}$

Idea of answering :

Molar mass of $N_2 = 2 \times 14 = 28$ g/mol

Molar mass of $O_2 = 2 \times 16 = 32$ g/mol

* Assuming that the mass of each sample is x g, hence :

- Number of N_2 moles $= \frac{x}{28}$
- Number of O_2 moles $= \frac{x}{32}$

∵ The volume of gas is directly proportional to the number of its moles at constant temperature and pressure.

$$\therefore \frac{\text{Volume of } N_2 \text{ gas}}{\text{Volume of } O_2 \text{ gas}} = \frac{\text{No. of } N_2 \text{ moles}}{\text{No. of } O_2 \text{ moles}}$$

$$\therefore \text{The volume ratio} = \frac{\frac{x}{28}}{\frac{x}{32}} = \frac{32}{28} = \frac{8}{7}$$

Answer : The correct choice is ⓐ

Test Yourself

Two balloons have the same volume at the same conditions of temperature and pressure, one of them is filled with helium and the other with carbon dioxide gas. Do you expect that they both have the same mass ?

....

....

Preliminary questions to remember the main concepts of the lesson

Answer them yourself

1 Choose the correct answer :

(1) One mole of hydrogen gas (at STP) contains each of the following, except .... [H = 1]

a. 6.02×10^{23} molecules of H_2

b. 2 g of H_2

c. 12.04×10^{23} atoms of H

d. 1 g of H_2

(2) Two samples of O_2 and H_2 gases have the same volume (at STP), they have equal .... [H = 1 , O = 16]

a. number of moles only. b. masses.

c. number of molecules only. d. a. and c. together.

(3) The volume of 4 g of hydrogen gas (at STP) equals .... [H = 1]

a. 89.6 L b. 44.8 L

c. 22.4 L d. 2 L

(4) The limiting reactant is the reactant which ....

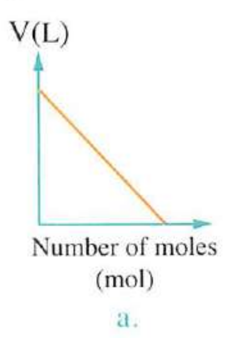
a. has the least mass.

b. has the least coefficient in a balanced equation.

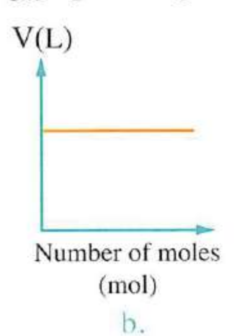
c. has the least number of moles.

d. yields the least amount of the products.

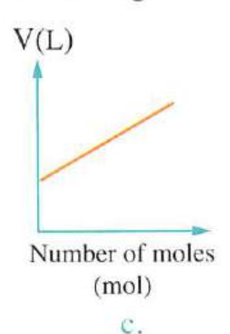
(5) Which of the following graphical figures represents Avogadro's law ?



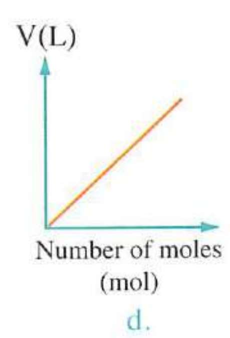
a.



b.



c.



d.

2 Give reasons for :

(1) Number of atoms in 32 g of oxygen does not equal the number of atoms in 32 g of sulphur.

(2) One mole of each of CO and CO_2 contains the same number of molecules despite the difference of their molecular masses.

(3) Number of atoms in 6 g of carbon equals the number of molecules in 14 g of carbon monoxide. [C = 12 , O = 16]

(4) One liter of O_2 gas contains the same number of molecules in 1 liter of Cl_2 gas (at STP).

(5) Volume of 1 mole of methane gas CH_4 equals the volume of 1 mole of ammonia gas NH_3 at the standard conditions.

(6) The volume of 26 g of acetylene gas (C_2H_2) is equal to the volume of 2 g of hydrogen gas H_2 (at STP). [C = 12 , H = 1]

3 Miscellaneous problems :

(1) Calculate the number of molecules of CO_2 in 0.5 mol of it.

(2) Calculate the volume of 3.5 mol of O_2 gas (at STP).

Open book questions

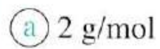
Answered

Multiple choice questions

Mole and Avogadro's number of molecules

1 What is the number of the molecules in a sample of ammonia NH_3 its mass equals 43.5 g ? [N = 14 , H = 1]

(a) 2.62×10^{25} molecules.
(b) 2.36×10^{23} molecules.
(c) 1.54×10^{24} molecules.
(d) 8.63×10^{-16} molecules.



2 The compound which the mass of its molecule = 2.93×10^{-22} g , its molar mass equals ....

(a) 2 g/mol
(b) 567 g/mol
(c) 168 g/mol
(d) 176.4 g/mol

3 What is the mass of one molecule of ethanoic acid $C_2H_4O_2$? [C = 12 , H = 1 , O = 16]

(a) 0.1 g (b) 9.97×10^{-23} g
(c) 3.6×10^{-23} g (d) 60 g

4 1 mol of nitrogen gas N_2 combines with 3 mol of hydrogen gas H_2 to form each of the following, <u>except</u> .... [N = 14 , H = 1]

(a) 2 mol of NH_3
(b) 34 g of NH_3
(c) $2 \times 6.02 \times 10^{23}$ molecules of NH_3
(d) 17 g of NH_3

5 What is the mass of phosphorus vapours which contains the same number of molecules that are found in 4.23 g of sulphur vapours ? [P = 31 , S = 32]

(a) 2.046 g (b) 4.224 g
(c) 8.184 g (d) 33.84 g

Mole and Avogadro's number of atoms

6 **Number of the atoms in 0.5 mol of acetic acid CH_3COOH equals ....**

(a) Avogadro's number.

(b) double Avogadro's number.

(c) four times Avogadro's number.

(d) eight times Avogadro's number.

7 **What is the number of atoms of oxygen in 0.1 mol of $CuSO_4.5H_2O$?**

(a) 5.42×10^{22} atoms. (b) 2.41×10^{23} atoms.

(c) 6.02×10^{23} atoms. (d) 5.42×10^{23} atoms.

8 **Number of atoms in 1.25 mol of NO_2 equals ....**

(a) 22.575×10^{23} atoms (b) 18.06×10^{23} atoms

(c) 3.75 atoms (d) 3 atoms

9 **4 g of sodium hydroxide contain ....** [Na = 23 , O = 16 , H = 1]

(a) 6.02×10^{23} atoms of H

(b) 4 g of atoms of Na

(c) 4 mol of NaOH

(d) 6.02×10^{22} atoms of Na

10 **The number of atoms of phosphorus vapour in 100 g of it equals ....** [P = 31]

(a) 1.94×10^{24} atoms. (b) 8.45×10^{25} atoms.

(c) 4.85×10^{23} atoms. (d) 2.2×10^{23} atoms.

11 **What is the length of the line which results from arranging the atoms of carbon which are present in 0.12 g of it, knowing that the diameter of carbon atom = 0.7 nm ?** [C = 12]

(a) 4.214×10^{21} m (b) 4.214×10^{12} m

(c) 2.107×10^{21} m (d) 2.107×10^{12} m

12 **A sample of oxygen gas its mass is 32 g contains ....** [H = 1 , O = 16]

(a) 6.02×10^{23} oxygen atoms.

(b) 1.204×10^{24} oxygen molecules.

(c) the same number of oxygen atoms found in 18 g of water.

(d) the same number of oxygen atoms found in 36 g of water.

13 What is the gram mass of a sample of aluminum contains half Avogadro's number of atoms ? [Al = 27]

(a) 6.75 g

(b) 13.5 g

(c) 27 g

(d) 54 g

14 The blood of the adult person contains about 2.64×10^{13} red blood cells, the mass of iron in them is 2.9 g

What is the number of iron atoms in each red blood cell ? [Fe = 55.85]

(a) 0.118×10^{10} atoms.

(b) 0.236×10^{10} atoms.

(c) 6.02×10^{23} atoms.

(d) 12.04×10^{23} atoms.

Mole and Avogadro's number of ions

15 On dissolving 1 mol of sodium chloride in water completely, the total number of ions equals ....

(a) Avogadro's number.

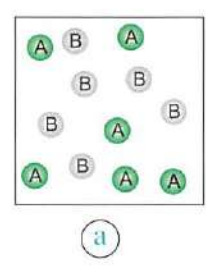
(b) 2 × Avogadro's number.

(c) 3 × Avogadro's number.

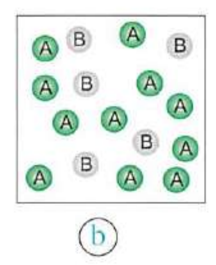
(d) 4 × Avogadro's number.

The limiting reactant

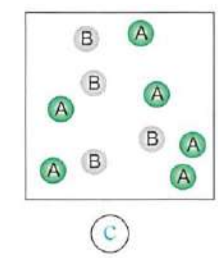
16 In which of the cases, illustrated in the following figures, (B) is considered the limiting reactant of the hypothetical reaction : $2A + B \longrightarrow C$?



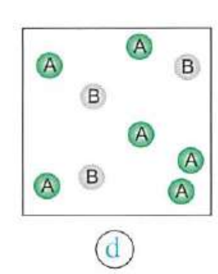
(a)



(b)



(c)



(d)

17 Phosphorus P_4 can be prepared from the following reaction :

	$2Ca_3(PO_4)_2$	+ $6SiO_2$	+ $10C$	$\longrightarrow 6CaSiO_3 + 10CO + P_4$
Molar mass	310 g/mol	60 g/mol	12 g/mol	
Masses present in reaction medium	3370 g	1795 g	650 g	

What is the limiting reactant of this reaction ?

(a) C (b) $Ca_3(PO_4)_2$

(c) SiO_2 (d) P_4

18 In the reaction : $AlCl_{3(aq)} + 3NaOH_{(aq)} \longrightarrow Al(OH)_{3(aq)} + 3NaCl_{(aq)}$

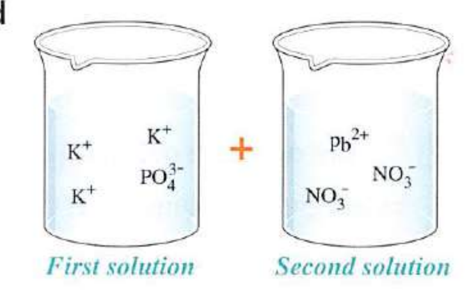
When 1 mol of aluminum chloride is added to 1 mol of sodium hydroxide.

What is the number of moles of the substance remaining at the end of the reaction ?

(a) 1 mol (b) $\frac{1}{3}$ mol

(c) $\frac{2}{3}$ mol (d) $\frac{1}{4}$ mol

19 On mixing the two solutions which are illustrated in the opposite figure, a precipitate is formed. What is the number of moles of the formed precipitate when 6 mol of the first solution reacts with 4 mol of the second solution ?



(a) 4 mol (b) 3 mol

(c) 2.3 mol (d) 1.33 mol

Avogadro's postulate

20 Two balloons have the same volume (at STP), the first is filled with helium gas, and the other with argon gas.

Which of the following statements represents correctly both of them ?

(a) Helium balloon contains higher number of atoms than argon balloon.

(b) Helium balloon contains lower number of atoms than argon balloon.

(c) Helium balloon contains the same number of atoms as argon balloon.

(d) Helium balloon has higher mass than argon balloon.

21 **Which of the following is an application of Avogadro's postulate ?** [C = 12 , H = 1]

(a) 11.2 L of O_2 gas contains the same number of molecules found in 11.2 L of H_2 gas.

(b) 1 liter of Cl_2 gas contains the same number of atoms found in 1 liter of SO_2 gas.

(c) The volume which is occupied by 26 g of C_2H_2 gas is larger than that occupied by 2 g of H_2 gas.

(d) The volume of 1 mol of CH_4 gas is lower than the volume of 1 mol of NH_3 gas.

22 **Which of the following is an application of Avogadro's postulate ?**

(a) Oxygen atom is 16 times heavier than hydrogen atom.

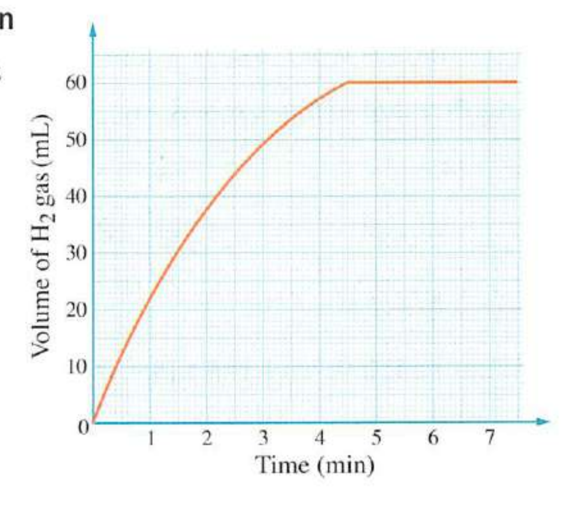
(b) 1 cm^3 of each of Ar , O_2 and NH_3 gases contains the same number of molecules at 80 K and 1 atm.

(c) Volume of hydrogen gas increases by increasing its number of moles at constant temperature and pressure.

(d) A mole of any gas such as CH_4 gas contains 22.4 L (at STP).

Mole and the volume of gas

23 **The opposite graph represents the relation between the volume of H_2 gas which evolves (at STP) on the reaction of a given amount of zinc completely with excess of dilute hydrochloric acid with time.**
What is the time which is consumed in the reaction of half of the amount of zinc ?



(a) 7 min

(b) 4.5 min

(c) 2.25 min

(d) 1.5 min

24 **The gas which the volume of 0.6 g of it = 80 mL (at STP), its molar mass = ...**

(a) 340 g/mol (b) 310 g/mol

(c) 168 g/mol (d) 85 g/mol

25 What is the mass of 0.25 L of the gas (X) (at STP) whose molar mass = 62.7 g/mol ?

(a) 0.69 g (b) 0.35 g

(c) 0.07 g (d) 0.035 g

26 The largest mass of oxygen gas among the following is the mass of .... [O = 16]

(a) 1 molecule (b) 11.2 L

(c) 1 mol (d) 1 atom

27 The volume of 12.04×10^{23} molecules of hydrogen gas (at STP) equals ....

(a) 89.6 L (b) 44.8 L

(c) 22.4 L (d) 2 L

28 Here are four identical flasks which contain equal amounts of different gases at the same conditions of temperature and pressure.

Which of these flasks is the largest in mass ? [Ne = 20 , C = 12 , H = 1 , O = 16 , N = 14]

Neon — (a)

Ethane C_2H_6 — (b)

Oxygen — (c)

Nitrogen — (d)

29 According to the reaction : $2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)}$

What is the volume of NO_2 gas which is produced from the reaction of 20 mL of NO gas with excess of oxygen gas at the same temperature and pressure ?

(a) 10 mL (b) 15 mL

(c) 20 mL (d) 30 mL

30 The volume of hydrogen which is required to produce 11.2 L of water vapour (at STP) equals ....

(a) 68.2 L (b) 11.2 L

(c) 44.8 L (d) 22.4 L

31 When 14 g of CO gas react with excess of oxygen, the volume of CO_2 gas which is produced equals (at STP) .... [C = 12 , O = 16]

(a) 89.6 L (b) 11.2 L

(c) 44.8 L (d) 22.4 L

32 0.3 g of magnesium reacts with excess hydrochloric acid according to the equation :

$$Mg_{(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2(aq)} + H_{2(g)}$$

What is the mathematical relation of the calculation of the volume of evolving hydrogen gas (at STP) ? [Mg = 24]

(a) $\frac{0.3 \times 2.24}{24}$ L (b) $\frac{0.3 \times 22.4}{24}$ L

(c) $\frac{0.3 \times 24}{22.4}$ L (d) $\frac{24}{0.3 \times 22.4}$ L

33 According to the reaction : $2SO_{2(g)} + O_{2(g)} \longrightarrow 2SO_{3(g)}$

If you know that atmospheric air contains 20% by volume oxygen gas. What is the volume of atmospheric air (at STP) which is required to react with 10 L of SO_2 gas ?

(a) 2 L (b) 5 L

(c) 10 L (d) 25 L

34 20 mL of CO gas burn in 40 mL of O_2 gas in a closed vessel according to the equation : $2CO_{(g)} + O_{2(g)} \xrightarrow{\Delta} 2CO_{2(g)}$

What is the total volume of the gases (at STP) in the vessel after the end of the reaction ?

(a) 20 mL (b) 40 mL

(c) 50 mL (d) 80 mL

35 Which of the following is the sum of the volumes of the gas and the vapour (at STP) produced from burning 5 g of methane gas CH_4 ? [C = 12 , H = 1]

(a) 5 L (b) 7 L

(c) 14 L (d) 21 L

36 Two closed vessels contain chlorine gas at the same conditions of temperature and pressure,

so if the first vessel whose volume = 1.3 L contains 6.7 mol of gas.

What is the number of moles in the second vessel whose volume = 2.33 L ?

(a) 0.452 mol (b) 3.74 mol

(c) 12 mol (d) 20.3 mol

Avogadro's law

37 **Which of the following examples is an application of Avogadro's law ?**

(a) When 3 balloons contain equal numbers of H_2 , O_2 and Cl_2 molecules, their volumes will be equal at the same temperature and pressure.

(b) The balloon which contains H_2 gas, its volume increases by increasing temperature at constant pressure.

(c) The volume of a balloon decreases with decreasing the number of moles of Ar gas in it at constant temperature and pressure.

(d) The volume of a piston which contains neon decreases by increasing the pressure at constant temperature.

Essay questions

Mole and Avogadro's number

38 **Calculate the mass** of sodium carbonate which contains 1.773×10^{17} carbon atoms.

[Na = 23 , C = 12 , O = 16]

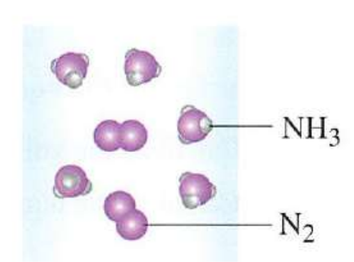
39 **Calculate the mass** of 100 atoms of copper (in grams). [Cu = 63.55]

The limiting reactant

40 In the reaction : $4NH_{3(g)} + 5O_{2(g)} \longrightarrow 4NO_{(g)} + 6H_2O_{(v)}$

Conclude the limiting reactant of the reaction on mixing 2 g of ammonia gas with 6 g of oxygen gas in suitable conditions for the reaction. [N = 14 , H = 1 , O = 16]

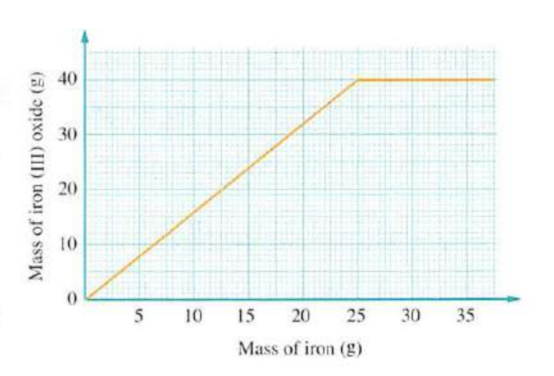
41 **The opposite figure represents the produced substances and the remaining unreacted substances on mixing hydrogen gas with nitrogen gas under suitable conditions for the reaction :**



(1) What is the limiting reactant in this reaction ?

(2) What is the number of the molecules of the limiting reactant in this reaction which are required to be added to the reaction mixture, so that all the reactants are consumed ?

42 **The opposite graph represents the masses of iron (III) oxide produced from the combination of iron with oxygen gas at suitable conditions :**



(1) Write the balanced symbolic chemical equation which represent this reaction.

(2) What is the limiting reactant of this reaction ? Explain.

Avogadro's postulate

43 **4 balloons are inflated with four different gases at the same conditions of temperature and pressure, the mass of :**

- **Hydrogen gas in the first balloon was 0.02 g**
- **Helium gas in the second balloon was 0.04 g**
- **Neon gas in the third balloon was 0.2 g**
- **Oxygen gas in the fourth balloon was 0.32 g**

Arrange these balloons according to their volumes, explain your answer with chemical calculations. [H = 1 , He = 4 , Ne = 20 , O = 16]

Mole and the volume of gas

44 Sodium carbonate reacts with hydrochloric acid, according to the equation :

$$Na_2CO_{3(s)} + 2HCl_{(aq)} \longrightarrow 2NaCl_{(aq)} + H_2O_{(\ell)} + CO_{2(g)}$$

Calculate the volume of CO_2 gas (at STP) which is produced from the reaction of 0.02 mol of sodium carbonate with excess of hydrochloric acid.

45 **In the reaction of 11.5 g of sodium with excess of water according to the equation :** $2Na_{(s)} + 2H_2O_{(\ell)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}$

(1) Calculate the volume of hydrogen gas (at STP) which is produced from this reaction.

(2) Calculate the number of sodium ions which are produced from this reaction.

[Na = 23 , H = 1]

46 The internal volume of a metallic cylinder is 30 L, it contains 32 g of gas (X) (at STP). Is gas (X) oxygen gas O_2 or methane gas CH_4 ? **Explain.** [C = 12 , H = 1 , O = 16]

New types of questions ? Answered

Choosing two out of five choices questions :

1 In the reaction : $CaCO_{3(s)} + 2HNO_{3(aq)} \longrightarrow Ca(NO_3)_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$

0.08 mol of nitric acid is added to 0.05 mol of calcium carbonate.
Which of the following is correct after the end of the reaction ?

(a) 0.05 mol of CO_2 is produced.
(b) 0.08 mol of $Ca(NO_3)_2$ is produced.
(c) 0.01 mol of $CaCO_3$ remains unreacted.
(d) 0.03 mol of HNO_3 remains unreacted.
(e) 0.04 mol of H_2O is produced.

2 The following equation is not balanced :

$$...... Zn + ... HNO_3 \longrightarrow ...... Zn(NO_3)_2 + ... NO + ... H_2O$$

After balancing the equation, it will be clear that ....

(a) the number of moles of HNO_3 equals the number of moles of H_2O
(b) the number of moles of nitrate group is the same in both the reactants and the products.
(c) on mixing 6 mol of Zn with 12.5 mol of HNO_3 , all the acid is consumed.
(d) on mixing 3 mol of Zn with 6 mol of HNO_3 , all zinc is consumed.
(e) the number of moles of zinc equals the number of moles of $Zn(NO_3)_2$

3 There are 3 samples of different gases at the same conditions of temperature and pressure :

(1) 5 g of neon gas. **(2) 2 g of hydrogen gas.**
(3) 22 g of carbon dioxide gas.

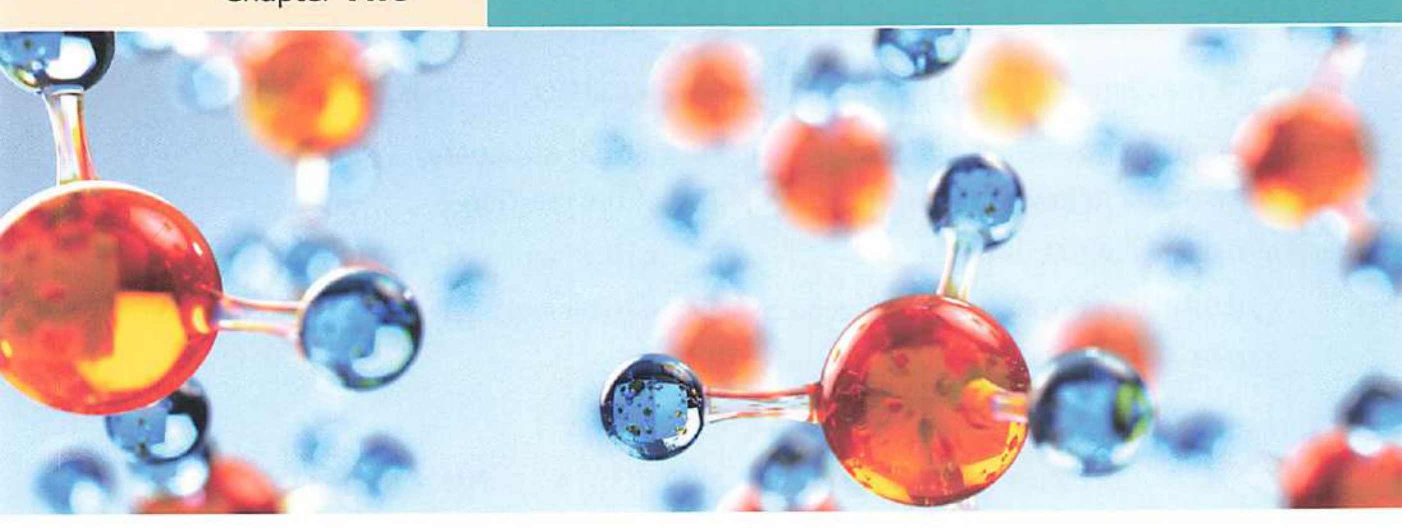
Which of the following represents correct relations between the volumes of these gases ? [Ne = 20 , H = 1 , C = 12 , O = 16]

(a) Volume of sample (1) = volume of sample (2).
(b) Volume of sample (2) = volume of sample (3).
(c) Volume of sample (2) > volume of sample (3).
(d) Volume of sample (3) > volume of sample (1).
(e) Volume of sample (2) < volume of sample (1).

4 Two samples, one of them is of ethylene gas C_2H_4 and the other is of nitrogen gas at the same conditions of temperature and pressure, they both contain the same number of molecules with the same ....

(a) volume.
(b) mass.
(c) number of moles.
(d) number of atoms.
(e) molar mass.

Calculation of chemical formula



Calculation of the mass percentages of the components of a compound

* The term **"mass percentage"** is used in chemical calculations, to calculate the percentage of each component in a given sample, **by :**

  - Knowing the molecular formula of the compound, and by knowing the gram atomic masses of the elements composing this compound

    from the relation :

For illustration

Law of definite proportions states that each chemical compound will always contain the same proportion of elements by mass, whatever the method of its preparation was.

$$\textbf{Mass percentage of an element in a compound} = \frac{\text{Mass of the element in a mole of the compound}}{\text{Molar mass of the compound}} \times 100\%$$

  - Experimental results which are obtained practically, **from the relation :**

$$\textbf{Mass percentage of an element in a sample} = \frac{\text{Mass of the element in the sample}}{\text{Mass of the sample}} \times 100\%$$

* The sum of the percentages of the elements composing the compound must equal **100%**

Worked Examples

1 Calculate the mass percentages of **the components of potassium sulphate salt.**

[K = 39 , S = 32 , O = 16]

Answer :

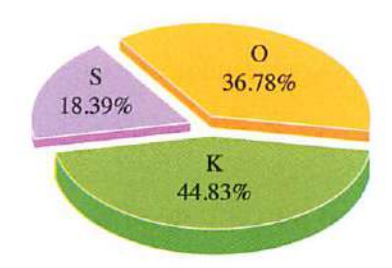
K_2SO_4	$\xrightarrow{\text{contains}}$	2K	+	S	+	4O
$((2 \times 39) + 32 + (4 \times 16))$ g		(2×39) g		32 g		(4×16) g
174 g		78 g		32 g		64 g

$$\text{Mass percentage of an element in a compound} = \frac{\text{Mass of the element in a mole of the compound}}{\text{Molar mass of the compound}} \times 100\%$$

Mass percentage of K in $K_2SO_4 = \frac{78}{174} \times 100\% = 44.83\%$

Mass percentage of S in $K_2SO_4 = \frac{32}{174} \times 100\% = 18.39\%$

Mass percentage of O in $K_2SO_4 = \frac{64}{174} \times 100\% = 36.78\%$



To check the correctness of the calculations :

The sum of the percentages of all components = 44.83 + 18.39 + 36.78 = **100%**

---

2 **Which of the following compounds has the highest mass percentage of hydrogen ?**

[H = 1 , Cl = 35.5 , O = 16 , S = 32]

(a) HCl
(b) H_2O
(c) H_2SO_4
(d) H_2S

Idea of answering :

Choices	Molar mass of the compound	Mass percentage of hydrogen in the compound
(a)	1 + 35.5 = 36.5 g/mol	$\frac{1}{36.5} \times 100\% = 2.74\%$
(b)	$(2 \times 1) + 16 = 18$ g/mol	$\frac{2}{18} \times 100\% = 11.11\%$
(c)	$(2 \times 1) + 32 + (4 \times 16) = 98$ g/mol	$\frac{2}{98} \times 100\% = 2.04\%$
(d)	$(2 \times 1) + 32 = 34$ g/mol	$\frac{2}{34} \times 100\% = 5.88\%$

Answer : The correct choice is (b)

3 **0.4 g of oxygen combines completely with 1.63 g of zinc to form zinc oxide,**

What is the mass percentage of oxygen in the product ?

(a) 4%

(b) 16.3%

(c) 19.7%

(d) 80.3%

Idea of answering :

Mass of the sample of zinc oxide = 0.4 + 1.63 = 2.03 g

$$\text{Mass percentage of an element in a compound} = \frac{\text{Mass of the element in the compound}}{\text{Mass of the compound}} \times 100\%$$

$$\text{Mass percentage of oxygen in the compound} = \frac{0.4}{2.03} \times 100\% = 19.7\%$$

Answer : The correct choice is (c)

---

4 **Mass percentage of carbon in the male hormone which is called testosterone is 79.167%, the mole of this hormone contains 19 mol of carbon atoms.**

What is the molar mass of this hormone ? [C = 12]

(a) 176.5 g/mol

(b) 190.7 g/mol

(c) 267.8 g/mol

(d) 287.99 g/mol

Idea of answering :

Mass of carbon in the mole of the hormone = 19 × 12 = 228 g

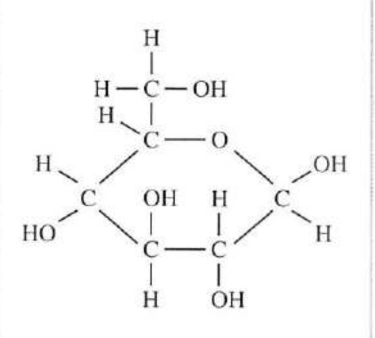
$$\text{Molar mass of the hormone} = \frac{\text{Mass of carbon in 1 mol of the hormone} \times 100\%}{\text{Mass percentage of carbon in 1 mol of the hormone}}$$

$$= \frac{228 \times 100\%}{79.167\%} = 287.99 \text{ g/mol}$$

Answer : The correct choice is (d)

Calculation of the chemical formula

* Chemical formulas are classified into three types, which are :

Empirical formula	Molecular formula	Structural formula
Is the chemical formula which represents the simplest integer numerical ratio of the atoms or ions of the elements composing the compound CH_2O *Empirical formula of glucose*	Is a chemical formula which represents the types and the numbers of the atoms or ions which compose the molecule (or the formula unit) of the compound $C_6H_{12}O_6$ *Molecular formula of glucose*	 *Structural formula of glucose*

* The empirical formula does not necessarily represent the chemical structure of the compound, as it is just a positive integer numerical ratio of the atoms or ions of the elements composing the compound, excluding some compounds whose empirical formulas are also their molecular formulas, such as CO and NO
* The empirical formula of a compound can be calculated by knowing its molecular formula, by reducing the number of the atoms or ions which compose the molecule or the formula unit to the simplest possible form.

Worked Example

Which of the following represents an empirical formula as well as a molecular formula at the same time ?

(a) C_5H_{12} (b) C_5H_{10} (c) C_4H_8 (d) C_4H_{10}

Idea of answering :

The empirical formula of each compound is calculated by reducing the number of the atoms which compose the molecule to the simplest form, as follows :

Molecular formula	C_5H_{12}	C_5H_{10}	C_4H_8	C_4H_{10}
Empirical formula	C_5H_{12}	CH_2 (divided by 5)	CH_2 (divided by 4)	C_2H_5 (divided by 2)

Answer : The correct choice is (a)

Calculation of the empirical formula

Worked Examples

1 Calculate the empirical formula of **an organic compound formed of carbon and hydrogen elements only, if you know that the mass percentage of carbon in this compound is 85.72% and that of hydrogen is 14.28%** [C = 12 , H = 1]

Idea of answering :

* Assuming the mass of the compound is 100 g (to simplify the calculations), hence the mass percentage represents the gram mass of each element, therefore :
  - Mass of carbon in 100 g of the compound is 85.72 g
  - Mass of hydrogen in 100 g of the compound is 14.28 g

① Calculation of the number of moles of the atoms of each element :

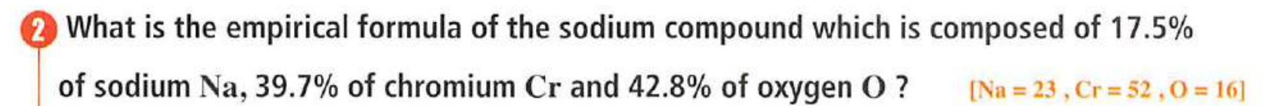
$$\text{Number of moles of element atoms} = \frac{\text{Mass of the element}}{\text{Gram atomic mass of this element}}$$

② Calculation of the ratio of the number of moles of the atoms of each element in one molecule of the compound, by dividing the number of moles by the smallest value of number of moles to find the simplest integer numerical ratio from which the empirical formula is estimated.

Answer :

C	H
Number of moles of C atoms $= \frac{85.72}{12} = 7.14$ mol	Number of moles of H atoms $= \frac{14.28}{1} = 14.28$ mol
Ratio of C moles number $= \frac{7.14}{7.14} = ①$	Ratio of H moles number $= \frac{14.28}{7.14} = ②$

CH_2



2 **What is the empirical formula of the sodium compound which is composed of 17.5% of sodium Na, 39.7% of chromium Cr and 42.8% of oxygen O ?** [Na = 23 , Cr = 52 , O = 16]

(a) $NaCrO_7$ (b) Na_2CrO_7

(c) $Na_2Cr_2O_7$ (d) $NaCrO$

Idea of answering :

Element	Na		Cr		O
Mass of the element in 100 g of the compound	17.5 g		39.7 g		42.8 g
Number of moles of element atoms	$\frac{17.5}{23} = 0.76$ mol		$\frac{39.7}{52} = 0.76$ mol		$\frac{42.8}{16} = 2.68$ mol
Ratio of number of moles of the element atoms	$\frac{0.76}{0.76} = 1$	:	$\frac{0.76}{0.76} = 1$	:	$\frac{2.68}{0.76} = 3.5$
Simplest integer numerical ratio of number of moles of the element atoms (× 2)	1 × 2 = ②	:	1 × 2 = ②	:	3.5 × 2 = ⑦
Empirical formula	$Na_2Cr_2O_7$				

Answer : The correct choice is (c)

3 **Calculate the empirical formula of an organic compound composed of carbon, hydrogen and oxygen, knowing that by burning 2.3 g of a sample of this compound in excess of oxygen gas, 4.4 g of carbon dioxide gas and 2.7 g of water vapour are formed.** [C = 12 , H = 1 , O = 16]

Idea of answering :

* Calculation of the mass of each of carbon and hydrogen elements in the sample by knowing the masses of CO_2 and H_2O produced from the burning process respectively.

* Calculation of the mass of oxygen by subtracting the sum of the masses of H and C from the mass of the compound.

Answer :

$CO_2 \xrightarrow{\text{contains}} C$		$H_2O \xrightarrow{\text{contains}} 2H$	
$12 + (2 \times 16) = 44$ g	12 g	$(2 \times 1) + 16 = 18$ g	$(2 \times 1) = 2$ g
4.4 g	? g	2.7 g	? g

Mass of C in the sample $= \frac{4.4 \times 12}{44} = 1.2$ g

Mass of H in the sample $= \frac{2.7 \times 2}{18} = 0.3$ g

$\therefore$ Mass of O in the sample = Mass of the sample – (Mass of C + Mass of H)

$= 2.3 - (1.2 + 0.3) = 0.8$ g

Element	C	H	O
Mass of the element	1.2 g	0.3 g	0.8 g
Number of moles of element atoms	$\frac{1.2}{12} = 0.1$ mol	$\frac{0.3}{1} = 0.3$ mol	$\frac{0.8}{16} = 0.05$ mol
Ratio of number of moles of the element atoms	$\frac{0.1}{0.05} = 2$:	$\frac{0.3}{0.05} = 6$:	$\frac{0.05}{0.05} = 1$
Empirical formula		C_2H_6O	

4 **Hydrocarbon C_xH_y is burnt according to the following unbalanced equation :**

$$C_xH_y + O_2 \xrightarrow{\Delta} CO_2 + H_2O$$

, so if you know that each 1 mol of this compound requires 5 mol of oxygen gas to be burnt producing 3 mol of carbon dioxide gas.

What is the chemical formula of this hydrocarbon mathematically ?

ⓐ C_2H_4

ⓑ C_3H_8

ⓒ C_4H_8

ⓓ C_4H_{10}

Idea of answering :

$$C_xH_y + 5O_2 \xrightarrow{\Delta} 3CO_2 + H_2O$$

∵ Number of moles of C atoms in the produced CO_2 = 3 mol

∴ The value of **x** in the hydrocarbon = 3

∵ Number of oxygen atoms is 7 in the products and 10 in the reactants.

∴ The equation will be balanced by multiplying the coefficient of water × 4

The balanced equation : $C_xH_y + 5O_2 \xrightarrow{\Delta} 3CO_2 + 4H_2O$

∵ Number of moles of H atoms in the produced $H_2O = 4 \times 2 = 8$ mol

∴ The value of **y** in the hydrocarbon = 8

∴ The chemical formula of the hydrocarbon is C_3H_8

Answer : The correct choice is (b)

Calculations of the molecular formula

Worked Example

Calculate the molecular formula of styrene, knowing that its molar mass is 104 g/mol and its empirical formula is CH [C = 12 , H = 1]

Idea of answering :

① Calculation of the number of the units of the empirical formula (n), using the relation :

$$(n) = \frac{\text{Molar mass of the compound}}{\text{Molar mass of the empirical formula}}$$

② Calculation of the molecular formula, using the relation :

$$\text{Molecular formula} = \text{Empirical formula} \times n$$

Answer :

- Molar mass of the empirical formula CH = 12 + 1 = 13 g/mol

$\therefore n = \frac{104}{13} = 8$

- $(CH)_8$ ⟹ C_8H_8

Test Yourself

An unknown compound its molar mass is 60 g/mol, it is composed of carbon, hydrogen and oxygen elements in the percentages shown in the following table :

Element	Carbon	Hydrogen	Oxygen
Gram atomic mass	12 g	1 g	16 g
Mass percentage	40%	6.67%	53.33%

What is the molecular formula of this compound ?

ⓐ C_4H_8O

ⓑ $C_2H_8O_2$

ⓒ C_2H_4O

ⓓ $C_2H_4O_2$

Idea of answering :

Element	C	H	O
Number of moles of element atoms "mol"	$\frac{......}{......}$ = ...	$\frac{......}{......}$ = 6.67 mol	$\frac{......}{......}$ = ...
Ratio of moles number	$\frac{......}{......}$ = ①	$\frac{......}{......}$ = ...	$\frac{......}{......}$ = ...
Empirical formula	....		
Molar mass of the empirical formula	....		
Number of units of the empirical formula	n = $\frac{......}{......}$ = 2		
Molecular formula	.... ➡		

Answer :

The correct choice is ....

Worked Examples

1 **A chemical compound its empirical formula is CH_2O and each 0.0835 mol of it contains 1 g of hydrogen.**

What is the molecular formula of this compound ?

ⓐ $C_2H_4O_2$ ⓑ $C_2H_2O_2$

ⓒ C_3H_6O ⓓ $C_6H_{12}O_6$

Idea of answering :

$(CH_2O)_n$	$\xrightarrow{\text{contains}}$	2n H
0.0835 mol		1 g
1 mol		? g

∴ Mass of H atoms in the molecular formula of the compound $= \frac{1}{0.0835} \simeq 12$ g

∴ Number of moles of H atoms in the molecular formula of the compound $= \frac{12}{1} = 12$ mol

∴ $2n = 12$

∴ Number of units of the empirical formula (n) = 6

∴ Molecular formula of the compound $(CH_2O)_6 \Rightarrow C_6H_{12}O_6$

Answer : The correct choice is ⓓ

---

2 **(A) and (B) are two compounds which are similar in the empirical formula but they differ in the molecular formula.**

Conclude the reason which leads to the previous result.

Answer :

(A) and (B) are similar in the empirical formula as they are similar in the ratios between the numbers of the atoms of the elements forming the molecule of each of them, but they are different in the molecular formula as they have different molecular masses, and hence different numbers of units of the empirical formula.

Calculation of the percentage of the actual yield

On carrying out any chemical reaction :

- The amount of the substance which is being obtained practically in the lab through this chemical reaction is known as the actual yield (or the practical yield or product).
- The amount of the substance which is expected to be obtained according to the mathematical calculations of the reaction equation is called the theoretical yield.

The actual yield is mostly less than the theoretical yield, this is due to a number of reasons, **among which are :**

- Reactants may contain impurities.
- The volatilization of a part of the products during the reaction.
- Some side reactions may take place resulting in the consumption of a part of the products.
- Sticking of a part of the products to the walls of the reaction container.

The percentage of actual yield can be calculated from the relation :

$$\textbf{The percentage of actual yield} = \frac{\textbf{Practical (actual) yield}}{\textbf{Theoretical yield}} \times 100\%$$

Worked Examples

1 **Methyl alcohol CH_3OH is prepared according to the reaction :**

$$CO_{(g)} + 2H_{2(g)} \xrightarrow{\Delta} CH_3OH_{(l)}$$

Calculate the percentage of the actual yield of the reaction, if you know that when 1.2 g of hydrogen gas react with excess of carbon monoxide gas, they produce 6.1 g of methyl alcohol. [C = 12 , H = 1 , O = 16]

Answer :

$2H_{2(g)}$	$\xrightarrow{\text{produce}}$	$CH_3OH_{(l)}$
$2(2 \times 1) = 4$ g		$(12 + 3 + 16 + 1) = 32$ g
1.2 g		? g

Molecule of methyl alcohol CH_3OH

The theoretical yield $= \frac{1.2 \times 32}{4} = 9.6$ g

The percentage of the actual yield $= \frac{6.1}{9.6} \times 100\% = 63.54\%$

2 **Ammonia gas reacts with excess of oxygen gas forming nitric oxide gas according to the equation : $4NH_{3(g)} + 5O_{2(g)} \longrightarrow 4NO_{(g)} + 6H_2O_{(v)}$**

, so if the mass of the actual yield of nitric oxide gas is 5 g and its percentage is 40%

What is the mass of the reactant ammonia gas ? [N = 14 , H = 1 , O = 16]

(a) 7.08 g (b) 12.5 g (c) 14.16 g (d) 25 g

Idea of answering :

$$\text{The theoretical yield} = \frac{\text{Actual yield}}{\text{Percentage of actual yield}} \times 100\%$$

$$= \frac{5}{40\%} \times 100\% = 12.5 \text{ g}$$

$$4NH_{3(g)} \xrightarrow{\text{produce}} 4NO_{(g)}$$

$4(14 + 3) = 68$ g $\qquad$ $4(14 + 16) = 120$ g

? g $\qquad$ 12.5 g

$$\therefore \text{Mass of ammonia gas} = \frac{68 \times 12.5}{120} = 7.08 \text{ g}$$

Answer : The correct choice is (a)

---

3 **72 g of phosphorus oxide (P_4O_{10}) react with excess of water to form phosphoric acid according to the equation : $P_4O_{10} + 6H_2O \longrightarrow 4H_3PO_4$**

, so if the percentage of the actual yield is 70%

What is the mass of phosphoric acid which is actually produced ? [H = 1 , P = 31 , O = 16]

(a) 392 g (b) 284 g (c) 99.381 g (d) 69.566 g

Idea of answering :

$$P_4O_{10} \xrightarrow{\text{produces}} 4H_3PO_4$$

$((4 \times 31) + (10 \times 16)) = 284$ g $\qquad$ $4((3 \times 1) + 31 + (4 \times 16)) = 392$ g

72 g $\qquad$? g

$$\text{The theoretical yield} = \frac{72 \times 392}{284} = 99.38 \text{ g}$$

$$\therefore \text{Mass of actual yield} = \frac{\text{Percentage of actual yield} \times \text{Theoretical yield}}{100\%} = \frac{70\% \times 99.38}{100\%} = 69.566 \text{ g}$$

Answer : The correct choice is (d)

4 **When 25.57 g of nitrogen were mixed with 4.45 g of hydrogen at suitable conditions, a reaction took place, this reaction is represented by the following equation :**

$$N_{2(g)} + 2H_{2(g)} \longrightarrow N_2H_{4(\ell)}$$

, so if the percentage of the actual yield is 82%

What is the actual yield of hydrazine N_2H_4 ? [N = 14 , H = 1]

(a) 23.94 g
(b) 29.2 g
(c) 32 g
(d) 35.6 g

Idea of answering :

Molar mass of hydrazine = (2 × 14) + (4 × 1) = 32 g/mol

N_2H_4 mass produced on consuming

All $N_{2(g)}$

$$N_{2(g)} \xrightarrow{\text{produces}} N_2H_{4(\ell)}$$

(2 × 14) = 28 g	32 g
25.57 g	? g

$$N_2H_4 \text{ mass} = \frac{25.57 \times 32}{28} = 29.2 \text{ g}$$

All $H_{2(g)}$

$$2H_{2(g)} \xrightarrow{\text{produce}} N_2H_{4(\ell)}$$

2(2 × 1) = 4 g	32 g
4.45 g	? g

$$N_2H_4 \text{ mass} = \frac{4.45 \times 32}{4} = 35.6 \text{ g}$$

∵ The lower mass of N_2H_4 is produced as a result of consuming all N_2

∴ N_2 is the limiting reactant of this reaction.

∴ The theoretical yield of N_2H_4 = 29.2 g

$$\text{Actual yield} = \frac{\text{Percentage of actual yield} \times \text{Theoretical yield}}{100\%}$$

$$\therefore \text{Actual yield of hydrazine } N_2H_4 = \frac{82\% \times 29.2}{100\%} = 23.94 \text{ g}$$

Answer : The correct choice is (a)

Preliminary questions to remember the main concepts of the lesson

Answer them yourself

1 Choose the correct answer :

(1) What is the mass percentage of chlorine in vanadinite whose molecular formula is $Pb_5(VO_4)_3Cl$? [Pb = 207 , V = 50.9 , O = 16 , Cl = 35.5]

a. 7.5% b. 3%

c. 2.5% d. 1.13%

(2) What is the mass percentage of iron in iron (III) oxide ? [Fe = 55.86 , O = 16]

a. 0.72% b. 28%

c. 30% d. 69.9%

(3) The empirical formula of $C_4H_8O_2$ is ....

a. $C_4H_4O_2$ b. C_2H_4O

c. $C_2H_8O_2$ d. C_4H_8O

(4) All the following compounds have the empirical formula CH_2O, except ....

a. HCHO b. CH_3COOH

c. $(COOH)_2$ d. $C_6H_{12}O_6$

(5) What is the empirical formula of the compound whose molecular formula is $C_6H_3(NO_3)_3$?

a. CHNO b. C_2HNO_3

c. $(C_2HNO_2)_3$ d. $C_6H_3N_3O_6$

(6) Number of units of the empirical formula in $C_2H_2O_4$ = ...

a. 1 b. 2

c. 3 d. 4

(7) If the empirical formula of a compound is CH_2 and its molar mass is 56 g/mol, so its molecular formula is .... [C = 12 , H = 1]

a. C_2H_4 b. C_3H_6

c. C_4H_8 d. C_5H_{10}

(8) The compound that each molecule of it consists of 3 atoms of carbon, 6 atoms of hydrogen and 1 atom of oxygen, its molecular formula is ....

a. $(CH)_3OH$ b. C_6H_3O

c. $(CH_3)_2CO$ d. $(CH_3)_2O$

(9) What is the percentage of the actual yield of zinc sulphate, if its calculated mass = 1.358 g and its actual mass = 1.146 g ?

a. 46% b. 23%

c. 11.5% d. 84.39%

2 Miscellaneous problems :

(1) Calculate the mass percentage of iron in siderite ore $FeCO_3$ [Fe = 56 , C = 12 , O = 16]

(2) Calculate the molecular formula of a compound whose molecular mass is 34 g and its empirical formula is HO [H = 1 , O = 16]

(3) Calculate the molecular formula of a compound whose molar mass is 70 g/mol , knowing that it contains 85.7% of carbon and 14.3% of hydrogen. [C = 12 , H = 1]

(4) 39.4 g of barium sulphate $BaSO_4$ are precipitated when an excess amount of potassium sulphate K_2SO_4 solution reacts with 40 g of barium chloride $BaCl_2$ solution. Calculate the percentage of the actual yield. [Ba = 137 , Cl = 35.5 , S = 32 , O = 16]

Open book questions

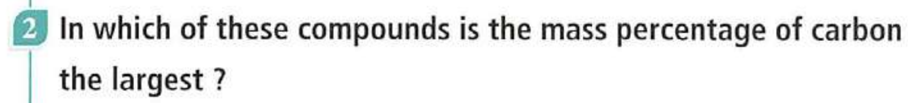
Answered

Multiple choice questions

Calculation of the mass percentages of the components of a compound

1 29.3 g of the element (X) are separated from 660 kg of molybdenite ore.
What is the mass percentage of (X) in the ore ?

(a) 0.0044% (b) 0.0022%
(c) 0.0011% (d) 0.0001%



2 In which of these compounds is the mass percentage of carbon the largest ?

(a) C_2H_2 (b) C_2H_4
(c) C_3H_8 (d) C_4H_{10}

[C = 12 , H = 1]

3 These compounds are similar in all the following, except ....

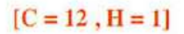
- $CH_3CH_2CH_2COOH$
- $OHCCH_2CH_2CH_2OH$
- $CH_3CHCHCH_2SH$

[C = 12 , H = 1 , O = 16 , S = 32]

(a) the mass percentage of carbon and hydrogen in each of them only.
(b) their molar masses only.
(c) that each of them contains 3 elements only.
(d) the number of atoms of the elements.

4 One mole of a compound contains 5 mol of carbon atoms, and they represent 40% of the mass of the compound.
What is the molar mass of this compound ? [C = 12]

(a) 30 g/mol (b) 67 g/mol
(c) 150 g/mol (d) 210 g/mol



5 A sample of hematite ore Fe_2O_3 its mass is 2.4 g, if the mass percentage of oxygen in it is 30.1%
What would be the mass of iron which can be extracted from it ?

(a) 1.2 g (b) 1.68 g
(c) 1.98 g (d) 2.2 g

Calculation of the chemical formula

6 Which of the following shows both the molecular formula and the empirical formula of this opposite compound ?

Choices	Molecular formula	Empirical formula
(a)	CH_2O	$C_2H_4O_2$
(b)	$C_4H_4O_4$	CHO
(c)	CH_2O_2	$C_4H_4O_4$
(d)	$C_2H_4O_2$	CH_2O

7 What is the empirical formula of the opposite compound ?

(a) $C_{10}H_8$ (b) C_8H_4

(c) C_5H_4 (d) C_3H_2

8 Which of the following compounds its empirical formula has the largest mass in grams ? [C = 12 , H = 1]

(a) C_6H_6 (b) C_4H_{10}

(c) C_3H_6 (d) C_2H_6

Calculation of the empirical formula

9 What is the chemical formula of the oxide of nitrogen which contains 63.64% by mass nitrogen ? [N = 14 , O = 16]

(a) NO (b) N_2O

(c) NO_2 (d) N_2O_4

10 What is the empirical formula of the oxide of sulphur which contains 50% by mass sulphur ? [S = 32 , O = 16]

(a) SO_3 (b) SO_2

(c) S_2O_4 (d) SO

11 What is the empirical formula of the hydrocarbon which contains 0.05 mol of carbon and 0.1 mol of hydrogen ?

(a) CH_4 (b) CH_2

(c) CH (d) C_2H

12 What is the empirical formula of the compound which is composed of the elements **X**, **Y** and **Z** in equal mass percentages ? [X = 20 , Y = 40 , Z = 60]

(a) X_3Y_2Z (b) XY_2Z_3

(c) XYZ (d) $X_6Y_3Z_2$

13 A compound consists of 3 elements in the following percentages :

- **C = 72%**
- **H = 12%**
- **O = 16%**

What is the ratio of the number of moles of carbon **C** : the number of moles of hydrogen **(H)** in the empirical formula of this compound ? [C = 12 , H = 1 , O = 16]

(a) 1 : 1 (b) 1 : 2

(c) 1 : 6 (d) 6 : 1

14 An ionic compound is composed of 29.08% sodium, 40.56% sulphur and 30.36% oxygen.

What is the formula of sulphur ion in this compound ? [Na = 23 , S = 32 , O = 16]

(a) $S_2O_3^{2-}$ (b) $S_2O_4^{2-}$

(c) $S_2O_5^{2-}$ (d) $S_2O_6^{2-}$

Calculation of the molecular formula

15 Which of the following represents a chemical compound whose molecular molar mass equals its empirical molar mass ?

(a) C_6H_6 (b) N_2H_4

(c) H_2O_2 (d) N_2O_5

16 The molar mass of a compound = 88 g/mol

What is the probable empirical formula of this compound ? [C = 12 , H = 1 , O = 16]

(a) CH_2 (b) CH_2O

(c) CH_3O (d) C_2H_4O

Questions marked by this mark their ideas are explained in the answers

17 A compound contains 3 elements in the following percentages :

- **C = 60%**
- **H = 8%**
- **O = 32%**

What is the possible molecular formula of this compound ?

(a) $C_5H_8O_2$ (b) C_5H_4O

(c) C_6HO_3 (d) C_7HO_4

[C = 12 , H = 1 , O = 16]

18 2.4 g of element (X) combined completely with 1.6 g of oxygen forming a compound with the molecular formula XO_2

What is the gram atomic mass of the element (X) ? [O = 16]

(a) 24 g/mol (b) 27 g/mol

(c) 35 g/mol (d) 48 g/mol

19 An organic compound with empirical formula CHCl, and its molar mass = 291 g/mol

What is the number of moles of carbon atoms in one mole of this compound ? [C = 12 , H = 1 , Cl = 35.5]

(a) 1 mol of atoms. (b) 3 mol of atoms.

(c) 6 mol of atoms. (d) 12 mol of atoms.

20 During the chemical analysis of a hydrocarbon gas, it was found that each carbon atom in it is binded to two hydrogen atoms.

What is the molecular formula of the gas, if its density equals 1.25 g/L ? [C = 12 , H = 1]

(a) CH_2 (b) C_2H_4

(c) C_2H_6 (d) C_4H_8

Calculation of the percentage of actual yield

21 11.9 g of $CHCl_3$ react with excess of chlorine gas to form 10.2 g of CCl_4 according to the equation : $2CHCl_3 + 2Cl_2 \longrightarrow 2CCl_4 + 2HCl$

What is the percentage of the actual yield ? [C = 12 , H = 1 , Cl = 35.5]

(a) 100% (b) 33.2%

(c) 66.5% (d) 86%

22 29 g of butane gas C_4H_{10} are burnt in excess of oxygen gas forming 0.9 g of water vapour H_2O

What is the percentage of the actual yield of water vapour ? [C = 12 , H = 1 , O = 16]

(a) 0.02% (b) 2%

(c) 10% (d) 36%

23 According to the reaction : $C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$

On adding 100 g of yeast to 1 mol of $C_6H_{12}O_6$, 32.3 g of C_2H_5OH are formed.

What is the percentage of the actual yield of C_2H_5OH ? [C = 12 , H = 1 , O = 16]

(a) 35.1% (b) 17.5%

(c) 100% (d) 32.3%

24 What is the percentage of the actual yield of the reaction of 2.5 mol of $Fe(NO_3)_3$ with 3.6 mol of Na_2CO_3 to form 6.3 mol of $NaNO_3$ according to the reaction :

$2Fe(NO_3)_3 + 3Na_2CO_3 \longrightarrow Fe_2(CO_3)_3 + 6NaNO_3$?

(a) 50%

(b) 84%

(c) 87.5%

(d) 100%

25 One of the students added a solution which contains 1 g of silver nitrate to another solution which contains 1 g of sodium chloride, hence a precipitate of silver chloride was formed, when its mass (after washing and drying) was calculated, it was found to be 0.732 g

What is the percentage of the actual yield of silver chloride ?

[Ag = 107.87 , N = 14 , O = 16 , Na = 23 , Cl = 35.5]

(a) 100% (b) 87.14%

(c) 25.72% (d) 12.86%

26 In the reaction : $CaCO_{3(s)} \xrightarrow{\Delta} CaO_{(s)} + CO_{2(g)}$

On heating 20 g of an impure sample of $CaCO_3$ (its molar mass = 100 g/mol), 8.4 g of CaO (its molar mass = 56 g/mol) are produced.

What is the percentage of the purity of calcium carbonate ?

(a) 15% (b) 25%

(c) 55% (d) 75%

27 A mixture formed of 12 L of H_2 gas and 11.2 L of Cl_2 gas at suitable conditions for the reaction.

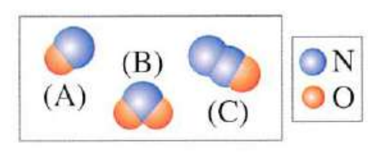
Which of the following is correct after the end of the reaction (at STP) ?

Choices	Volume of formed HCl	Percentage of remaining unreacted substance
(a)	22.4 L	50%
(b)	24 L	50%
(c)	22.4 L	6.67%
(d)	24 L	6.67%

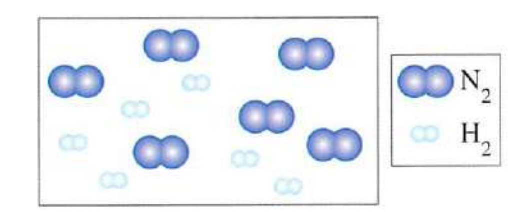
Essay questions and problems

Calculation of the mass percentages of the components of a compound

28 **Explain by chemical calculations** which of the three compounds illustrated in the opposite figure contains 46.7% by mass nitrogen. [N = 14 , O = 16]



29 Nitrogen gas N_2 reacts with hydrogen gas H_2 to form ammonia gas NH_3, so assuming that some of the units - in the opposite figure - may react together forming ammonia.
Calculate the mass percentage of the remaining unreacted substance after the end of the reaction.



30 **When is the molecular formula** of a compound also its empirical formula ?

31 **Calculate the molar mass of the empirical formula of each of the following compounds :** [C = 12 , O = 16 , H = 1 , Si = 28 , Cl = 35.5]

(1) O = C = O

(2)
```
      Cl   Cl
      |    |
Cl – Si – Si – Cl
      |    |
      H    H
```

Calculation of the empirical formula

32 The mass of a sample of a certain compound = 80 g, this mass contains 32 g of sulphur and the rest of it is oxygen ..
Calculate the empirical formula of this compound. [S = 32 , O = 16]

Calculation of the molecular formula

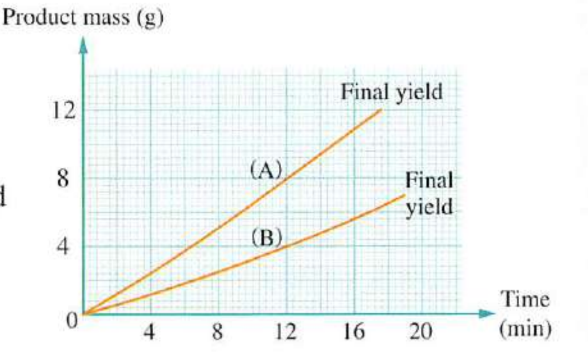
33 **Deduce the molecular formula of a compound** whose molar mass is 136 g/mol, and it consists of carbon, hydrogen and oxygen elements in the ratios which are illustrated in the opposite table.

Element	Gram atomic mass	Percentage
C	12 g	70.59 %
H	1 g	5.89 %
O	16 g	23.52 %

Calculation of the percentage of actual yield

34 **What is wrong in saying that** the actual yield of a compound is 24.2 g and its theoretical yield = 24 g ?

35 **The opposite figure represents the change in the amounts of the susbstances which are produced from a given reaction :**



(1) Which curve represents the theoretical yield and which represents the practical (actual) yield ? Explain your answer.

(2) Calculate the percentage of the actual yield 12 min after the beginning of the reaction.

36 The following reaction is carried out at high temperatures :

$$2NH_{3(g)} + 3CuO_{(s)} \xrightarrow{\Delta} N_{2(g)} + 3Cu_{(s)} + 3H_2O_{(v)}$$

If 6.63 g of nitrogen gas are actually produced from the reaction of the mixture which is composed of 18 g of NH_3 and 90.4 g of CuO.

Calculate the percentage of the actual yield. [N = 14 , H = 1 , Cu = 63.5 , O = 16]

37 The combustion reaction of carbon takes place according to the equation :

$$C_{(s)} + O_{2(g)} \xrightarrow{\Delta} CO_{2(g)}$$

Calculate the burnt mass of carbon in excess of oxygen, if the percentage of the actual yield = 89.3%, and the actual volume of CO_2 gas (measured at STP) equals 10 L

[C = 12 , O = 16]

New types of questions ? Answered

Choosing two out of five choices questions :

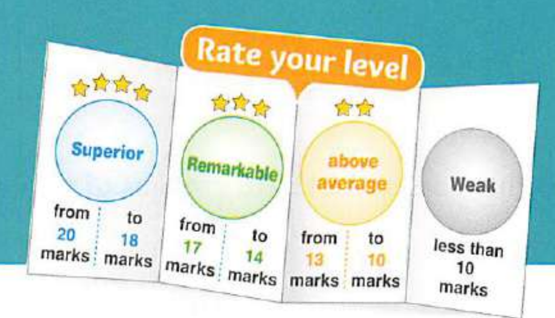
1 Which of the following are empirical formulas ?

(a) N_2O_4
(b) C_4H_8
(c) NH_3
(d) S_2O_6
(e) V_2O_5

2 Which of the following salts loses 45% of its mass when all the water that is present in it is evaporated ? [$H_2O = 18$, $Na_2SO_4 = 142$, $CuSO_4 = 159.5$, $NiSO_4 = 154$, $KAl(SO_4)_2 = 258$, $MgSO_4 = 120$]

(a) $Na_2SO_4.10H_2O$
(b) $CuSO_4.5H_2O$
(c) $NiSO_4.7H_2O$
(d) $KAl(SO_4)_2.12H_2O$
(e) $MgSO_4.7H_2O$

Exam model on Unit 2



Choose the correct answer for the questions

1 What is the volume of H_2 gas (at STP) which is produced from the reaction of 12.15 g of magnesium with excess of hydrochloric acid ? [Mg = 24 , H = 1]

(a) 1 L (b) 2 L

(c) 5.6 L (d) 11.34 L

2 The opposite equation is not balanced : $S + HNO_3 \longrightarrow H_2SO_4 + NO_2 + H_2O$

What is the coefficient of water in the balanced equation ?

(a) 1 (b) 2

(c) 4 (d) 6

3 Which of the following contains the highest number of molecules ? [H = 1 , N = 14 , O = 16 , C = 12]

(a) 1 g H_2 (b) 2 g N_2

(c) 4 g O_2 (d) 11 g CO_2

4 What is the empirical formula of arsenic oxide in which the percentage of arsenic (As) equals 65.2% ? [As = 75 , O = 16]

(a) As_2O (b) As_2O_3

(c) As_2O_5 (d) As_4O_{10}

5 What is the molar mass of potassium dichromate $K_2Cr_2O_7$? [K = 39 , Cr = 52 , O = 16]

(a) 107 g/mol (b) 255 g/mol

(c) 294 g/mol (d) 242 g/mol

6 In the reaction : $K_2CO_{3(s)} + 2HNO_{3(aq)} \longrightarrow 2KNO_{3(aq)} + H_2O_{(l)} + CO_{2(g)}$

What is the number of moles of carbon dioxide which are produced from the reaction of 69 g of potassium carbonate with excess of nitric acid ? [K = 39 , C = 12 , O = 16]

(a) 0.25 mol (b) 0.5 mol

(c) 1 mol (d) 2 mol

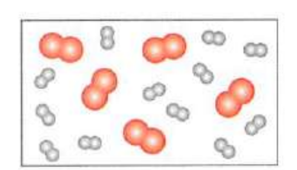
7 What is the mass of 3.01×10^{23} atoms of sodium ? [Na = 23]

(a) 46 g (b) 23 g

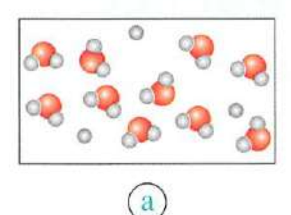
(c) 11.5 g (d) 0.5 g

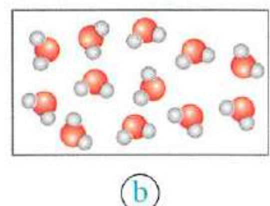
8 Hydrogen gas reacts with oxygen gas according to the equation : $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(v)}$

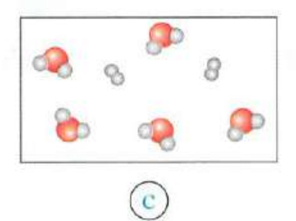
If you have the mixture which is shown in the opposite figure.

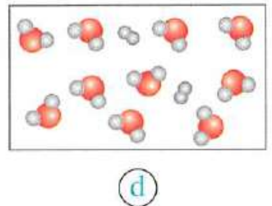


What would be the correct choice which represents the produced mixture after the end of the reaction ?


(a)


(b)


(c)


(d)

9 On burning 50 mL of the hydrocarbon C_xH_y in excess of oxygen gas, 200 mL of carbon dioxide gas and 250 mL of water vapour are formed (at STP).

What is the molecular formula of this hydrocarbon ?

(a) C_2H_4 (b) C_3H_8

(c) C_4H_8 (d) C_4H_{10}

10 In the reaction :

$$Mg_3N_{2(s)} + 6H_2O_{(\ell)} \longrightarrow 3Mg(OH)_{2(s)} + 2NH_{3(g)}$$

If the percentage of the actual yield = 80%

What is the mass of ammonia NH_3 which can be prepared from 19 kg of Mg_3N_2 ?

[Mg = 24 , N = 14 , H = 1]

(a) 2.6 kg

(b) 6.46 kg

(c) 5.17 kg

(d) 15 kg

11 A sample (X) of a compound contains 23 g of sodium, 27 g of aluminum and 114 g of fluorine.

Calculate the mass of sodium in the sample (Y) of this compound whose mass = 102 g

....

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.... 2 marks

12 Calculate the mass of chloride ions in a mixture which contains 1 mol of the compound XCl_2 and 1 mol of the compound YCl_2 [Cl = 35.5]

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.... 2 marks

13 The following equation is not balanced :

$$Sr(NO_3)_{2(aq)} + K_2SO_{4(aq)} \longrightarrow KNO_{3(aq)} + SrSO_{4(s)}$$

(1) **Rewrite** the previous equation after balancing.

....

(2) **Write** the net ionic equation which represents the previous reaction.

....

.... 2 marks

(14) **Conclude the molecular formula** of the compound whose molar mass is 78 g/mol and its empirical formula is NaO [Na = 23 , O = 16]

....

....

....

....

.... / 1 mark

(15) The molar mass of dibromoethane $C_2H_4Br_2$ is 188 g/mol , this compound is used as an insecticide.

Calculate the mass percentage of bromine in this compound. [Br = 80]

....

....

....

.... / 1 mark

(16) **Calculate the number** of hydrogen atoms in 1 mol of $(NH_4)_2HPO_4$

....

....

....

.... / 1 mark

(17) The following symbolic equation represents the reaction of aluminum with sulphur to form aluminum sulphide : $16Al_{(....)} + 3S_{8(....)} \longrightarrow 8Al_2S_{3(s)}$

Write the physical state of each of aluminum and sulphur in the previous equation.

....

.... / 1 mark

UNIT 3 Solutions, Acids and Bases

Chapter One — Solutions and Colloids.

Lesson 1	From	The beginning of the chapter.
	Until	Before concentrations of solutions.
Lesson 2	From	Concentrations of solutions.
	Until	Before colligative properties of solutions.
Lesson 3	From	Colligative properties of solutions.
	Until	Before mixtures properties.
Lesson 4	From	Mixtures properties.
	Until	The end of the chapter.

Chapter Two — Acids and Bases.

Lesson 1	From	Uses of acids and bases.
	Until	Before Classification of acids and bases.
Lesson 2	From	Classification of acids and bases.
	Until	Before salts.
Lesson 3	From	Salts.
	Until	The end of the chapter.

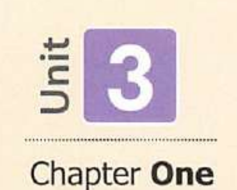
Exam model on the unit

Learning outcomes of unit three

By the end of this unit, the student will be able to :

- Explain what is meant by solution and distinguish between the types of solutions by practical experiments.
- Describe the solubility process, the factors affecting it and the heat changes accomplished with it.
- Show the concentration of solutions using different methods.
- Calculate the concentration of the solution using one of the concentration units.
- Identify the general properties of solutions "solid in liquid".
- Represent the graphical relationship between the concentration of solution, the vapor pressure, the change in its boiling and freezing points.
- Compare between the colloid solutions and the real solutions in terms of the size of their compositions.
- Prepare some simple colloids and show their importance in our everyday life.
- Explain what is meant by acid and base and their classifications.
- Compare between the different theories to define the acid and the base.
- Distinguish between acids and bases using indicators and the pH-meter.
- Understand how salts are formed, their naming and the pH values of their solutions.

The included life topic : Rationalization of consumption.

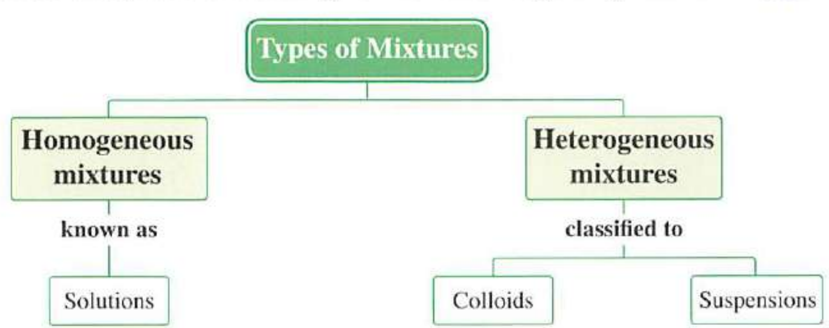


Lesson 1

From The beginning of the chapter

Until Before concentrations of solutions

★ Mixtures can be classified according to their homogeneity into two types :



Solutions	Colloids	Suspensions
Their components can't be distinguished by the naked eye or the electronic microscope	Their components can be distinguished by the electronic microscope only	Their components can be distinguished by the naked eye
Examples		Examples
• Table salt in water. • Table sugar in water. • Cobalt (II) chloride in water.	• Aerosols. • Hair gel. • Mayonnaise emulsion. • Blood. • Milk.	• Table salt in kerosene. • Table sugar in kerosene. • Cobalt (II) chloride in kerosene. • Oil in water. Oil Water
Cobalt (II) chloride $CoCl_2$ aqueous solution	*Milk*	*Water-oil suspension*

Homogeneous mixtures (Solutions)

* If a small quantity of a substance (as sugar) is added to a large amount of another substance (as water) and disappears in it.

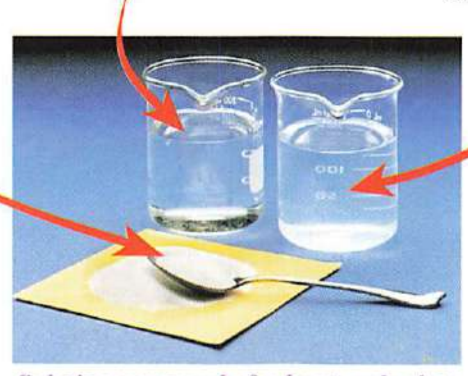
Therefore :

- Sugar is **a solute**.
- Water is **a solvent**.
- The produced mixture is **a solution**.

Solute
The minor component that has the lower ratio in the solution.

Solvent
The major component that has the larger ratio in the solution.

Solution
It is a homogeneous mixture of two or more substances which are chemically unreacted.



Solution composed of solvent and solute

Note

In aqueous solutions, water is always the solvent regardless its quantity (proportion) in the solution

* **When two samples of one solution are analyzed, it will be found that they contain the same contents in the same ratios, which proves the homogeneity of the solution, for example the sweet taste of sugar solution in water is the same in all of its parts,** because of the homogeneity of the sugar solution, as each part of the solution contains the same amount (concentration) of sugar.

* **Solutions are necessary** in the biological processes that occur inside the living organisms, they may be an essential requirement for the occurrence of certain chemical reactions.

Types of solutions

Solutions can be classified according to :

First **The physical state of the solvent.**

Second **The ability to conduct electricity.**

Third **The degree of saturation.**

First According to the physical state of the solvent

The solutions are divided into

A Gaseous solutions. **B** Liquid solutions. **C** Solid solutions.

★ **The following table shows some examples of these different types :**

Types of solutions	Solute	Solvent	Examples
Gaseous solutions	Gas	Gas	• Atmospheric air. • Natural gas.
Liquid solutions	Gas	Liquid	• Soft drinks. • Oxygen dissolved in water.
	Liquid	Liquid	• Alcohol in water. • Ethylene glycol (antifreeze) in water.
	Solid	Liquid	• Sugar in water. • Salt in water.
Solid solutions	Gas	Solid	Hydrogen gas on palladium or platinum
	Liquid	Solid	Liquid mercury dissolved in solid silver (silver amalgam) $Ag_{(s)}/Hg_{(\ell)}$
	Solid	Solid	Alloys such as nickel-chromium (nichrome) alloy

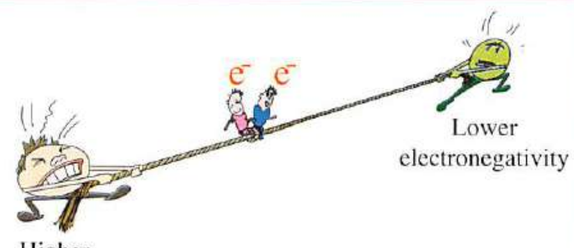
For illustration

Mercury forms with solid metals such as silver, gold or platinum a kind of solution known as metal amalgam

* **Our study will focus on (solid in liquid) type of solutions, in which water is always the solvent.**

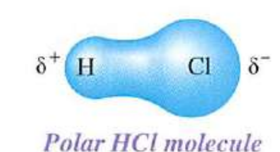
Scientific knowledge

- **Electronegativity :** It is the ability of an atom to attract the electrons of the bond to itself.



The atom with higher electronegativity attracts the electrons of the bond

- **Polar bond :** It is the covalent bond between two atoms which are different in electronegativity, the higher electronegative atom carries a partial negative charge (δ^-), while the other atom carries a partial positive charge (δ^+).
- **Polar molecules :** They are the molecules that have an end carrying a partial positive charge (δ^+) and another end carrying a partial negative charge (δ^-).

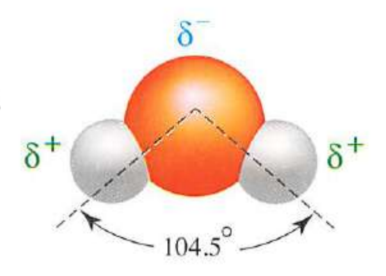


Polar HCl molecule

- **The degree of polarity depends on :**
  - Difference in electronegativity between the bonded atoms.
  - Geometry of the molecule.
  - Bond angles.

Water as a polar solvent

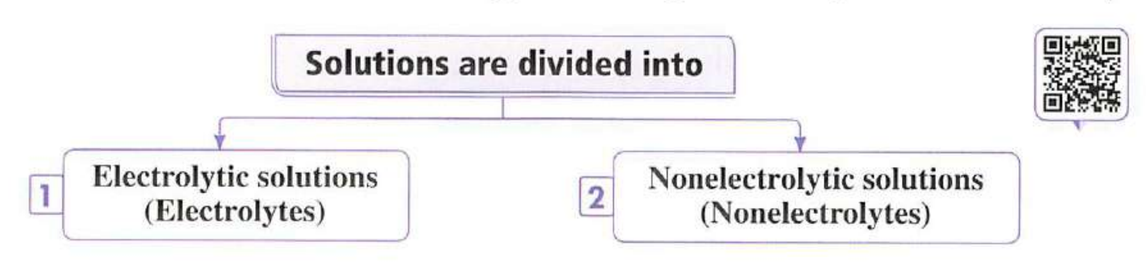
* Water is a polar solvent, because water molecule has one end carries a partial negative charge δ^- (oxygen), and the other end carries a partial positive charge δ^+ (hydrogen).
* Water is the most powerful polar solvent due to the presence of two polar (O – H) bonds in each molecule, this is because of the high electronegativity of oxygen (much more than hydrogen), as well as the wide angle between these two bonds (104.5°).



Water H_2O is a polar molecule

Second According to the ability to conduct electricity

Solutions of substances are divided into two types according to the ability to conduct electricity.



1 Electrolytes

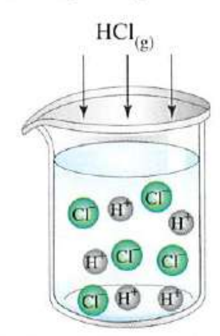
Are substances whose solutions (or moltens) can conduct electricity by the movement of the hydrated (or the free) ions.

Electrolytes are divided into :

Strong electrolytes

Are substances which are completely ionized and conduct electricity strongly

Strong electrolytes conduct electricity to a great extent

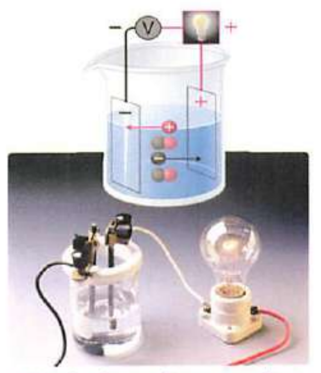


Hydrochloric acid is completely ionized

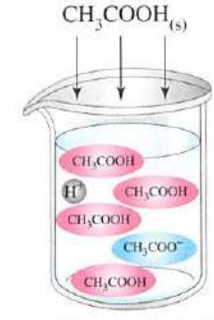
Completely ionized substances are substances in which all their molecules are dissociated into ions when they dissolve in water

Weak electrolytes

Are substances which are partially ionized and conduct electricity weakly



Weak electrolytes conduct electricity to a weak extent



Acetic acid is partially ionized

Incompletely ionized substances are substances in which a small part of their molecules are ionized into ions when they dissolve in water

Examples

Strong electrolytes:

* **Ionic compounds like :**
  - Sodium chloride $NaCl$
  - Sodium hydroxide $NaOH$
* **Polar covalent compounds like :**
  Hydrochloric acid $HCl_{(aq)}$, (which is produced when hydrogen chloride gas $HCl_{(g)}$ dissolves in water).

Weak electrolytes:

- Ammonium hydroxide NH_4OH (ammonia in water).
- Acetic acid CH_3COOH
- Pure water H_2O

Notes

* All organic acids are weak electrolytes.

* All solid salts do not conduct electricity, while when they dissolve in water (as $NaCl_{(s)}$) (**i.e.** being in aqueous solution form as $NaCl_{(aq)}$), then they conduct electricity.

* All gases – under normal conditions of temperature and pressure – do not conduct electricity.

Application

* Hydrogen chloride gas $HCl_{(g)}$ does not conduct electricity, while when it dissolves in water it forms hydrochloric acid $HCl_{(aq)}$ which is a good electric conductor, this dissolving process is represented by the following equation :

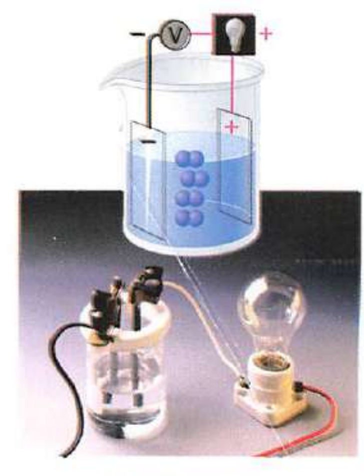
$$H_2O_{(l)} + HCl_{(g)} \longrightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$

H^+ ions bind with water molecules forming hydronium ions $H_3O^+_{(aq)}$ (hydrated protons).

$$H_2O_{(l)} + H^+_{(aq)} \longrightarrow H_3O^+_{(aq)}$$

2 Nonelectrolytes

Are substances whose solutions or moltens do not conduct electricity, as they have no free or hydrated ions.



Nonelectrolytes
(Do not conduct electricity)

Examples

* Ethyl alcohol.

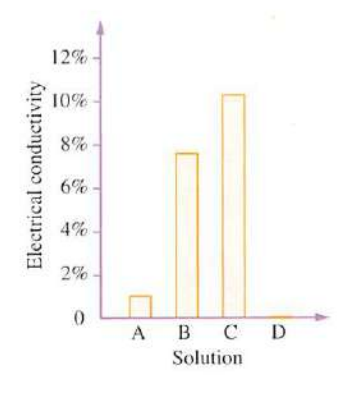
* Sugar solution.

Worked Example

The opposite graphical figure shows the percentages of the electrical conductivity of 4 different solutions, (with no particular order) :

- Glucose.
- Sodium chloride.
- Acetic acid.
- Sodium carbonate.

Which of the following represents each of the solutions (A), (B), (C) and (D) ?



Choices	Solution (A)	Solution (B)	Solution (C)	Solution (D)
(a)	Acetic acid	Sodium chloride	Sodium carbonate	Glucose
(b)	Sodium carbonate	Acetic acid	Glucose	Sodium chloride
(c)	Glucose	Sodium chloride	Acetic acid	Sodium carbonate
(d)	Sodium chloride	Acetic acid	Sodium carbonate	Glucose

Idea of answering :

∵ Glucose (a sugar in water solution) is a nonelectrolytic solution which does not conduct electricity.

∴ Solution (D) represents glucose.

∴ The choices (b) and (c) are excluded.

∵ Acetic acid is an incompletely ionized substance which conducts electricity poorly.

∴ Solution (A) represents acetic acid.

∴ The choice (d) is excluded.

Answer : The correct choice is (a)

Third According to the degree of saturation

Solutions are divided into

- **Unsaturated solution**
- **Saturated solution**
- **Supersaturated solution**

Unsaturated solution is the solution which contains a relatively small amount of the solute and can accept larger amount of this solute at a constant temperature.

Saturated solution is the solution which contains the maximum amount of the solute that can be dissolved at a certain temperature.

Supersaturated solution is the solution which by heating accepts larger amount (than the maximum) of the solute after being saturated.

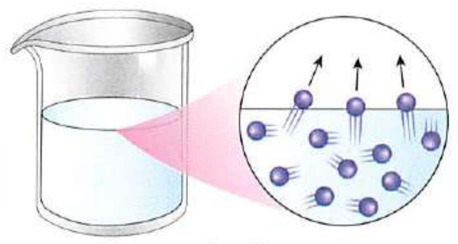
* **It is possible to convert :**

1. **Saturated solution to supersaturated solution**, by heating the saturated solution and adding more solute to it.
2. **Supersaturated solution to saturated solution**, by two methods, which are :
   a. **Cooling :** Cool the supersaturated solution and leave it for a short time, the excess solute will be separated (precipitate) from the solution.
   b. **Crystallization :** Put small crystals from the solute in the supersaturated solution and leave it for a short time, the solute molecules will be precipitated as crystals on the surface of the seeding crystals.

Formation of crystals from supersaturated solution

Dissolving process

* Although water seems to be static in the beaker, but its molecules are really in a continuous motion, especially the surface molecules (by the effect of their kinetic energy).
* When a solute is added to water, dissolving occurs **as follows :**



Water molecules are in a continuous motion

If the solute is

Ionic substance	**Polar substance**
So the particles of the solute dissociate during the dissolving process into :	
positive and negative ions	polar molecules
which bind to the molecules of the solvent	

* **In the light of the previous, dissolving process can be defined as follows :**
* *Dissolving process is the process that occurs when the solute decomposes or dissociates into negative and positive ions or into separated polar molecules. Each of them binds to the molecules of the solvent.*

Application Dissolving of sodium chloride NaCl in water :

* When a crystal of sodium chloride is placed in water, the following occurs :

- The polar water molecules collide with the crystals of NaCl by their kinetic energy.
- Water molecules attract Na^+ and Cl^- ions by directing the suitable pole towards each of them to be separated from NaCl crystal.
- Water molecules which surround the ions isolate positive ions from negative ions and prevent their binding again, where the ions become hydrated and then they disperse regularly to form a solution.

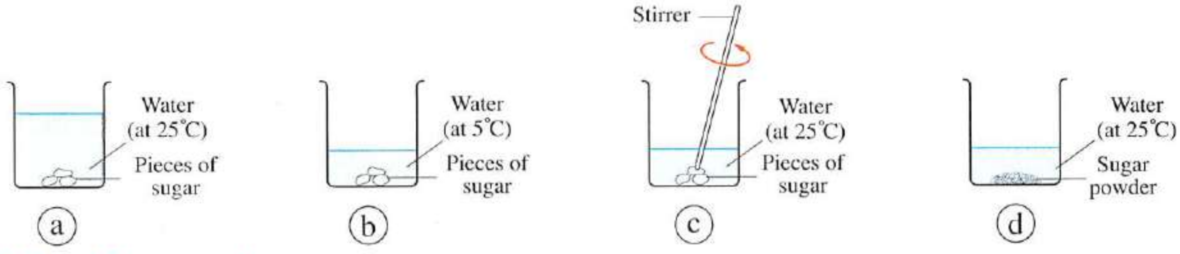
Solute
Table salt (NaCl)
Solution
Table salt solution
Solvent
H_2O molecules surround Na^+, Cl^- ions

The speed of the dissolving process depends on :

- Surface area of the solute.
- The stirring process.
- Temperature.

Worked Example

In the experiment illustrated by the following figures, 2 g of sugar are used with different volumes of water at different temperatures.
What is the state in which the dissolution process of solute in the solvent takes longer time ?



Idea of answering :

- Dissolving process increases (the time of dissolution decreases) by the increase of each of the following :
  - Surface area of the solute, hence the choice (d) is excluded.
  - Stirring process, hence the choice (c) is excluded.
  - Temperature, hence the choice (a) is excluded.

Answer : The correct choice is (b)

Solubility

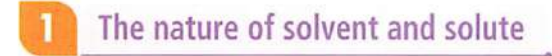
* The ability of the solute to be dissolved in a certain solvent, or the ability of the solvent to dissolve a certain solute can be determined by the indication of what is known as solubility.

* **Solubility** *is the mass of the solute in grams, which dissolves in 100 g of the solvent to form a saturated solution at standard temperature and pressure (STP), and it is estimated in (g solute / 100 g of water).*

Factors affecting the solubility

1 The nature of solvent and solute.

2 The temperature.

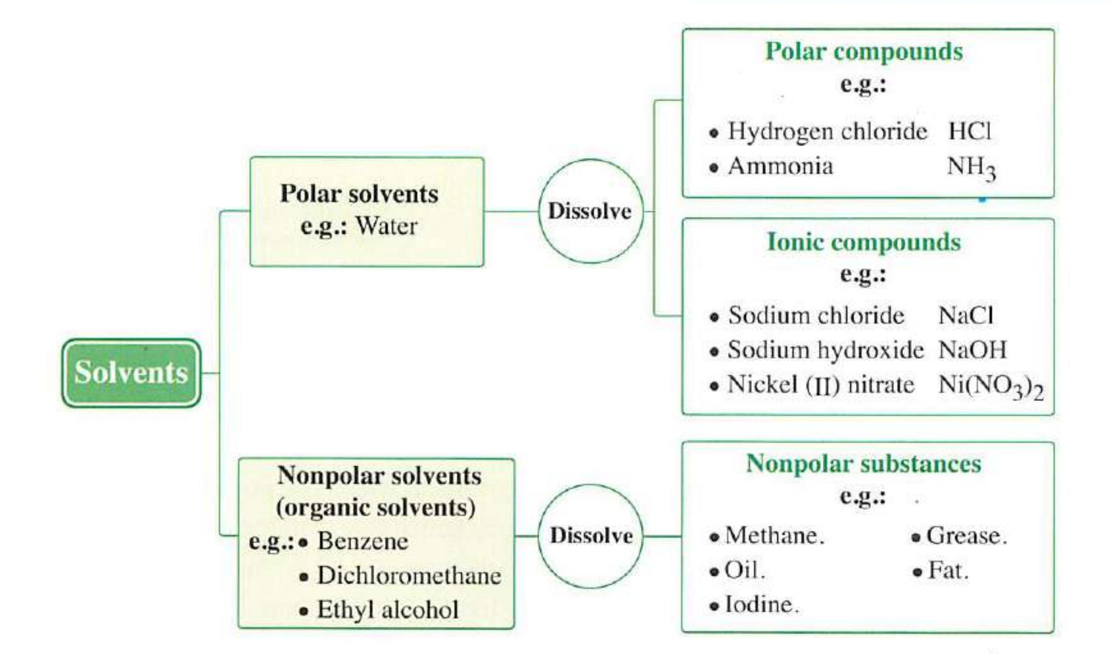


1 The nature of solvent and solute

"Likes dissolve likes" is a well known statement which controls the solubility process, this statement can be explained as follows :

For illustration

* Most of the covalent compounds dissolve in organic solvents.
* HCl is a covalent compound which dissolves in polar solvents as well as organic solvents.

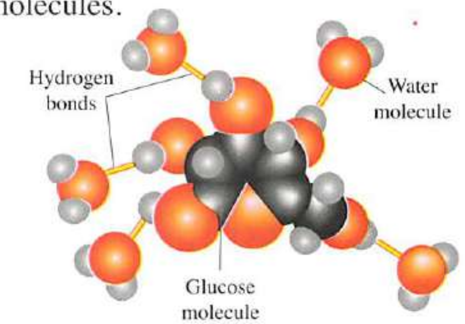


Applications Solubility of some substances in polar and nonpolar solvents.

1. **Oil is insoluble in water,** because water is a polar solvent and oil is a nonpolar substance, so oil doesn't dissolve in water.

2. **Oil is soluble in benzene,**
because oil (nonpolar substance) is dispersed between molecules of benzene (nonpolar solvent), due to the weak bonds between the benzene molecules.

3. **Sugar is soluble in water, although sugar is a nonpolar substance,** because water molecules form hydrogen bonds with sugar molecules, because they contain polar hydroxyl groups (OH^-) as shown in the figure.

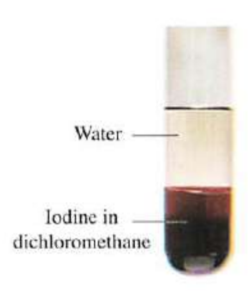


Dissolving of glucose in water due to formation of hydrogen bonds

4. **The opposite figure shows a tube containing a heterogeneous mixture of water and dichloromethane.**
It is observed that : dichloromethane does not dissolve in water, because water is a polar solvent, while dichloromethane is a nonpolar substance, where the nonpolar substances don't dissolve in polar solvents.

By adding

Iodine to this heterogeneous mixture



It dissolves in dichloromethane, but not in water, **because** iodine is a nonpolar substance and dichloromethane also is a nonpolar solvent, but water is a polar solvent, where the nonpolar substances don't dissolve in the polar solvents, but dissolve in the nonpolar solvents.

The green nickel (II) nitrate to this heterogeneous mixture

It dissolves in water but not in dichloromethane, **because** nickel (II) nitrate is an ionic substance and water is a polar solvent, while dichloromethane is a nonpolar solvent, where the ionic substances dissolve in the polar solvents, but don't dissolve in the nonpolar solvents.

Test Yourself

A wall is painted with an old paint, a part of it is mistakenly sprayed with a new paint, so if the two paints can not dissolve in the same solvent.

Which of the following solvents can remove the new paint without damaging the old paint ?

Solvent	Old paint	New paint
(a)	Does not dissolve in it	Does not dissolve in it
(b)	Does not dissolve in it	Dissolves in it
(c)	Dissolves in it	Does not dissolve in it
(d)	Dissolves in it	Dissolves in it

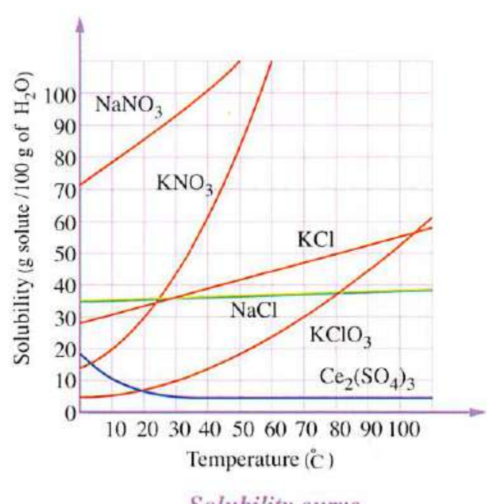
Answer : The correct choice is ....

2 Effect of temperature on solubility

The Following diagram shows the solubility of several salts at different temperatures.

There are three cases :

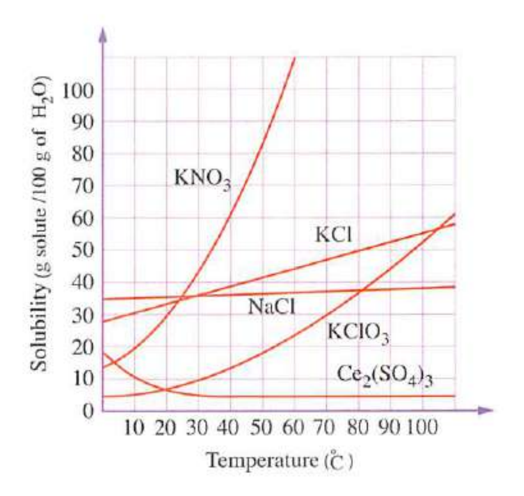
- **The solubility of most salts increases greatly by increasing the temperature, such as $NaNO_3$, KNO_3 , KCl and $KClO_3$**
- **The solubility of some salts increases slightly by increasing the temperature, such as NaCl**
- **The solubility of some salts decreases by increasing the temperature, such as $Ce_2(SO_4)_3$**



Solubility curve (Relation between solubility and temperature)

Worked Examples

1 Study the diagram, then answer the following questions :



(1) What is the substance whose solubility increases with decreasing the temperature ?

(2) What is the difference in the mass of potassium nitrate which is dissolved in a saturated solution of it, when heated from 20°C to 40°C ?

(3) Calculate the mass of KCl required to be dissolved in 200 g of water to form a saturated solution at 80°C

(4) Calculate the mass of the precipitated $KClO_3$ after cooling a saturated solution of it, from 70°C to 30°C

Answer :

(1) $Ce_2(SO_4)_3$, its solubility increases with decreasing temperature.

(2) The difference in the mass of potassium nitrate = 60 – 30 = **30 g**

(3) It is clear in the solubility curve that at 80°C, 50 g of KCl dissolve in 100 g of water to form a saturated solution.

KCl	is dissolved in →	H_2O
50 g		100 g
? g		200 g

$\therefore$ Mass of dissolved KCl in 200 g of $H_2O = \frac{50 \times 200}{100} = \mathbf{100\ g}$

(4) Mass of the precipitated $KClO_3$ = 30 – 10 = **20 g**

2 **The opposite table shows the masses of the solutes and those of the solvents in 4 different solutions at 60°C**
In which of these solutions the mass of the solute in its saturated solution (at 60°C) is the largest ?

Solution	Solute mass	Solvent mass
(W)	10 g	50 g
(X)	20 g	60 g
(Y)	30 g	120 g
(Z)	40 g	80 g

(a) (W)   (b) (X)

(c) (Y)   (d) (Z)

Idea of answering :

* Compare the mass of the solute in each solution relative to a constant mass of the solvent (let it be 120 g of the solvent in each solution).

Solution (W)	Solution (X)	Solution (Y)	Solution (Z)
Solute ⟶ Solvent 10 g 50 g x g 120 g $\therefore x = \frac{10 \times 120}{50}$ $= 24$ g	Solute ⟶ Solvent 20 g 60 g x g 120 g $\therefore x = \frac{20 \times 120}{60}$ $= 40$ g	Solute ⟶ Solvent 30 g 120 g $\therefore x = 30$ g	Solute ⟶ Solvent 40 g 80 g x g 120 g $\therefore x = \frac{40 \times 120}{80}$ $= 60$ g

∴ The mass of the solute in the solution (Z) at 60°C is the largest.

Answer : The correct choice is (d)

Preliminary questions to remember the main concepts of the lesson

Answer them yourself

1 Choose the correct answer :

(1) Mixture of cobalt (II) chloride in water is ....

a. heterogeneous. b. a solution.

c. a suspension. d. a colloid.

(2) What is the mixture whose components can be distinguished by the naked eye ?

a. Sodium chloride in water mixture. b. Oil in water mixture.

c. Blood. d. Hair gel.

(3) Blood and milk are examples of ....

a. liquid solutions. b. solid solutions.

c. colloids. d. suspensions.

(4) Ethylene glycol in water is a ....

a. liquid in liquid solution. b. solid in liquid solution.

c. gas in liquid solution. d. liquid in gas solution.

(5) The angle between the two polar bonds in water molecule is ....

a. 140.5° b. 90°

c. 105.4° d. 104.5°

(6) One of the strongest electrolytes is ....

a. $H_2O_{(l)}$ b. benzene.

c. $HCl_{(g)}$ d. $HCl_{(aq)}$

(7) On dissolving hydrogen chloride gas in water, the positive hydrogen ion H^+ ....

a. separates and stay as it is.

b. separates to combine with water molecule.

c. separates and evolves as a gas.

d. does not even separate.

(8) The saturated solution can be converted to supersaturated solution by ....

a. heating and crystallization.

b. heating and adding an excess amount of solute.

c. cooling and crystallization.

d. heating and filtration.

(9) All the following substances dissolve in water, except ....

a. sodium hydroxide.
b. iodine.
c. nickel (II) nitrate.
d. table salt.

(10) Sugar dissolves in water, due to the formation of ....

a. covalent bonds.
b. ionic bonds.
c. metallic bonds.
d. hydrogen bonds.

2 Give reasons for :

(1) The mixture of table salt in water is a solution, while the mixture of table salt in kerosene is a suspension.

(2) Water is a polar solvent.

(3) Hydrochloric acid is a strong electrolyte.

(4) In aqueous solutions H^+ ions are not found in their single form.

(5) Sugar dissolves in water, although it is a nonpolar compound.

Open book questions

Answered

Multiple choice questions

Mixtures and solutions

1 **Which of the following is a mixture ?**

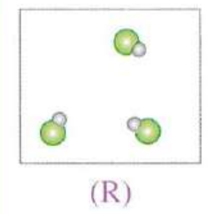
(a) $NaCl_{(\ell)}$

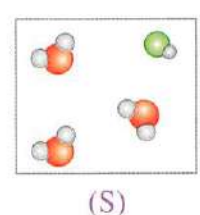
(b) $NaCl_{(aq)}$

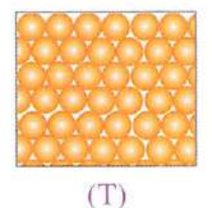
(c) $H_2O_{(v)}$

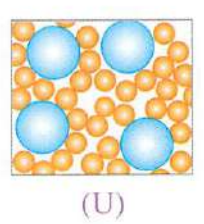
(d) $H_2O_{(s)}$

2 **The following four figures represent the arrangements of the particles which form four different substances :**


(R)


(S)


(T)


(U)

Which of the following choices represents these substances correctly ?

Choices	(R)	(S)	(T)	(U)
(a)	Compound	Compound	Element	Compound
(b)	Element	Compound	Compound	Mixture
(c)	Element	Mixture	Compound	Compound
(d)	Compound	Mixture	Element	Mixture

3 **What is the type of the mixture which is composed of water, silt and table salt ?**

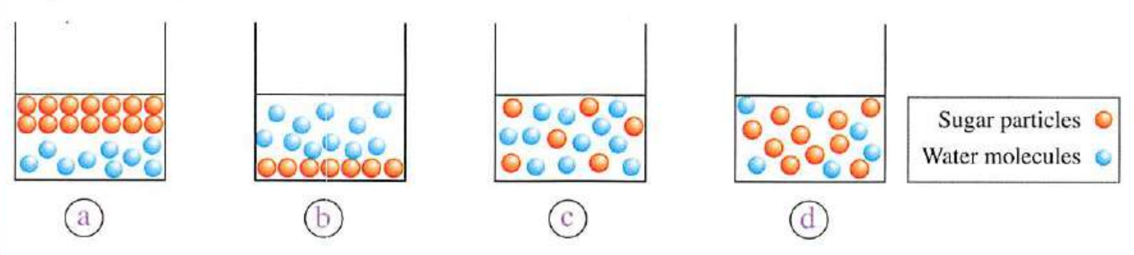
(a) Homogeneous mixture.

(b) Heterogeneous mixture.

(c) Solution.

(d) Blend.

4 Which of the following diagrams expresses the solution produced from dissolving sugar in water ?



5 The opposite table shows the percentages of some of atmospheric air components.

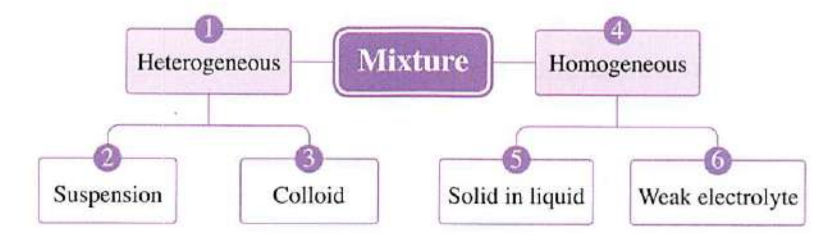
Gases	Nitrogen	Oxygen	Carbon dioxide
Percentages	78%	21%	0.03%

Which of the following choices represents each of the solvent and the solute ?

Choices	Solvent	Solute
ⓐ	O_2 , N_2	CO_2
ⓑ	O_2	CO_2 , N_2
ⓒ	N_2	CO_2 , O_2
ⓓ	CO_2	O_2 , N_2

Types of solutions

6 The following chart shows some of the properties of the mixtures :



Which of the numbers shown in the previous chart represents the properties of the formed mixture which is illustrated in the opposite figure ?

ⓐ (1) and (2).

ⓑ (1) and (3).

ⓒ (4) and (5).

ⓓ (4) and (6).

7 **What is the physical state of the solvent in amalgams ?**

(a) Gas only. (b) Liquid only.

(c) Solid only. (d) Gas, liquid or solid.

8 **Which of these solutions is a good electric conductor ?**

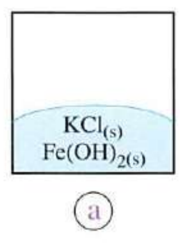
(a) Solution of magnesium chloride in water.

(b) Solution of glucose in water.

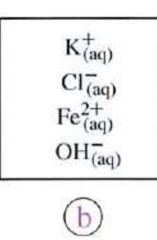
(c) Solution of table sugar in ethyl alcohol.

(d) Solution of iodine in ethyl alcohol.

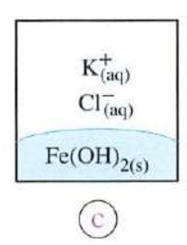
9 **Which of the following figures represents the heterogeneous mixture which is produced from mixing KOH solution and $FeCl_2$ solution ?**



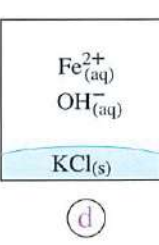
(a)



(b)



(c)



(d)

Dissolving process

10 **A crystal of potassium chloride is formed of ....**

(a) KCl molecules. (b) Cl and K atoms.

(c) Cl^+ and K^- ions. (d) Cl^- and K^+ ions.

11 **The opposite table shows the solubility of three substances (X), (Y) and (Z) in different solvents.**
What is the type of each of the substances (X) , (Y) and (Z) ?

Substance	Solubility
(X)	Dissolves in water but not in alcohol
(Y)	Dissolves in alcohol but not in water
(Z)	Dissolves in both water and alcohol

Choices	(X)	(Y)	(Z)
(a)	Ionic	Polar	Polar
(b)	Nonpolar	Ionic	Nonpolar
(c)	Ionic	Nonpolar	Polar
(d)	Polar	Nonpolar	Ionic

12 On adding a strip of magnesium to a beaker containing a solution of hydrogen chloride dissolved in dichloromethane, it was noticed that no reaction takes place. What is the action which can be taken to start a reaction between these contents in the beaker that yields hydrogen gas ?

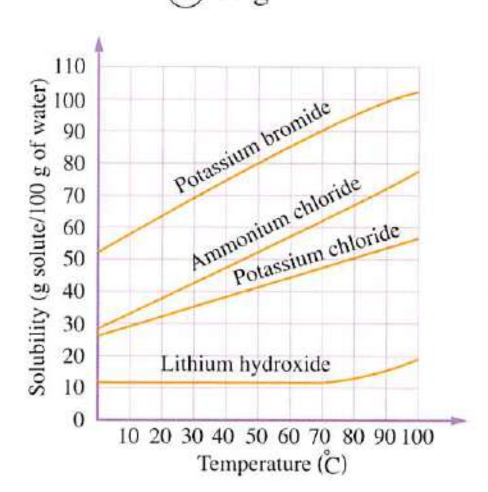
(a) Heating the contents of the beaker. (b) Adding water to the beaker.

(c) Stirring the contents of the beaker well. (d) Adding more dichloromethane.

13 If the solubility of a salt in water equals (20 g/100 g of H_2O) at a certain temperature. What is the mass of the salt required to be added to 300 g of water to obtain a saturated solution at the same temperature ?

(a) 20 g (b) 40 g (c) 60 g (d) 80 g

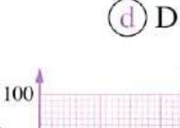
14 The opposite graph represents the solubility curve of some substances in water, and the table shows their solubilities at 40°C :



Solution	Solute	Mass of solute/100 g of H_2O (at 40°C)
(A)	KBr	75.4 g
(B)	NH_4Cl	48.8 g
(C)	KCl	32 g
(D)	LiOH	13 g

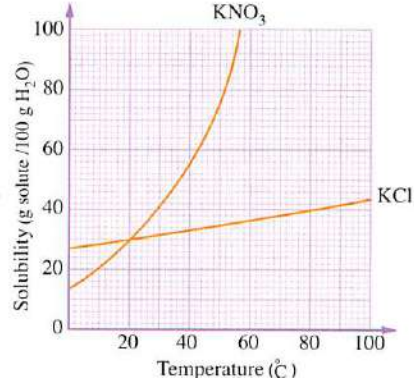
Which of these solutions shown in the table is unsaturated ?

(a) A (b) B (c) C (d) D

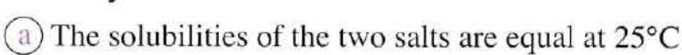


15 The opposite graph represents the solubility curves of both potassium nitrate KNO_3 and potassium chloride KCl in water.

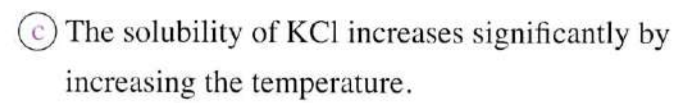
Which of the following explains these two solubility curves ?



(a) The solubilities of the two salts are equal at 25°C



(b) The solubility of KNO_3 is always higher than that of KCl



(c) The solubility of KCl increases significantly by increasing the temperature.

(d) The solubility of KNO_3 is the highest at 56°C

Essay questions

Types of solutions

16 **Determine the solvent in the homogeneous mixture** which is composed of 20 mL of ethanol with 100 mL of propanol. **Explain.**

17 **Classify the components of the following solutions by filling in the spaces in the next table :**

Solution	Type of solution	Solute state	Solvent state
(1) Atmospheric air	Gas	Gas	....
(2) Sea water	....	....	....
(3) Bronze alloy	Solid	....	....

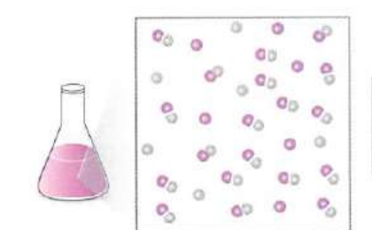
18 **There are two samples (A) and (B) :**

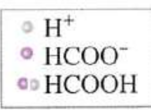
- **Sample (A) contains a salt solution, prepared by dissolving table salt in water.**
- **Sample (B) contains a solid salt, its chemical formula is NaCl**

(1) Classify the components of each sample whether, (Element / Compound / Mixture).

(2) Mention two differences between the samples (A) and (B) in the light of your former classification in the part (1).

19 The opposite figure represents a homogeneous mixture of formic acid HCOOH with water.
Is this mixture a good electric conductor or a weak electric conductor ? Explain.
"**Note :** Water H_2O molecules are neglected in the figure for simplification".





20 **The two following figures represent** the electric conductivity of two equal volumes of pure water, 1 g of sodium sulphate salt is added to one of them and 1 g of table sugar is added to the other (in no particular order).
Indicate the type of the solution in each figure.

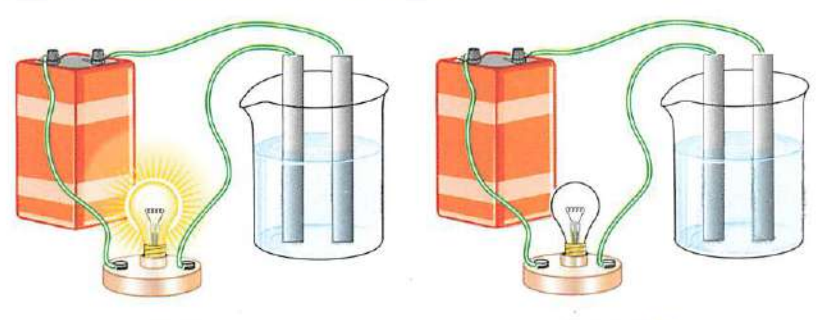


Figure (A) Figure (B)

21 **Study the illustrated processes in the following figures, then answer :**

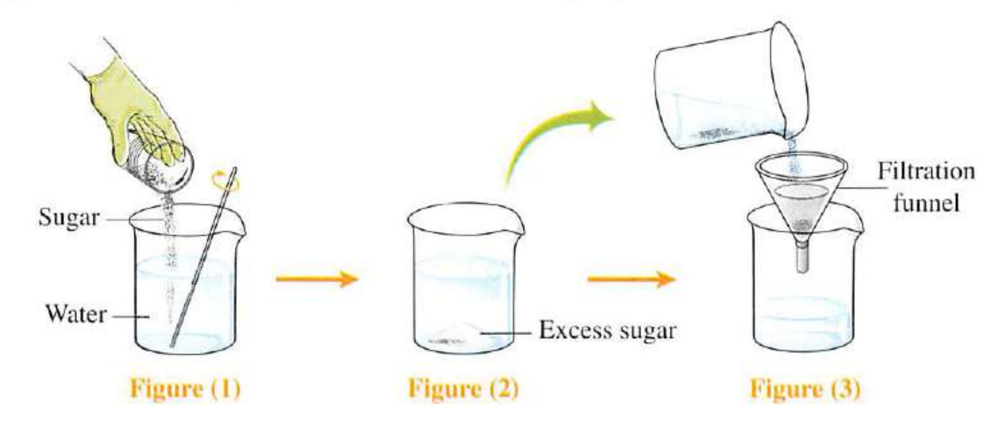


Figure (1) Figure (2) Figure (3)

(1) What is the type of the formed solution in the beaker illustrated in figure (3) ? Explain.

(2) What is expected to happen when the solution in the beaker illustrated in figure (2) is heated ? What is the type of the formed solution ?

22 **How can you differentiate between** a saturated solution **and** a supersaturated solution of the same substance (at 40°C) with two different methods ?

Dissolving process

23 **30 g of sodium bromide are dissolved in 100 g of water at temperature 20°C, so an aqueous solution of sodium bromide is formed, this trial is repeated in 100 g of kerosene :**

(1) Can the particles of sodium bromide in the aqueous solution be distinguished by naked eye ? Explain.

(2) What is the difference between the type of the mixture of sodium bromide with water and its mixture with kerosene ?

24 **The opposite figures illustrate two different mixtures of a polar substance and an organic substance :**

(1) Which of the opposite figures represents a mixture of water and ethanol ? Explain.

(2) Blue copper (II) sulphate salt is added to the heterogeneous mixture, so the lower part becomes blue unlike the upper part as shown in figure (1), explain the reason for that.

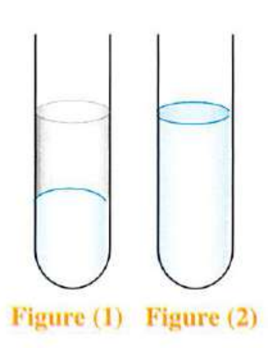
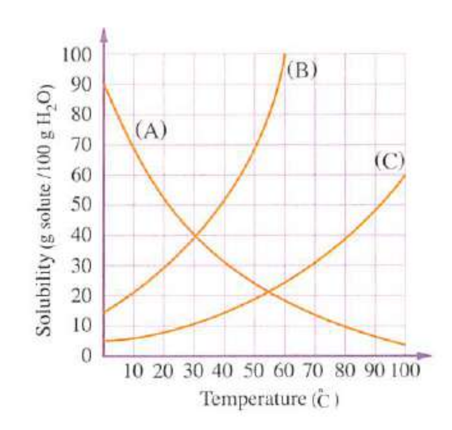


Figure (1) Figure (2)

25 **The opposite figure represents the change in the solubility of three substances (A), (B) and (C) as a result of the change in the temperature :**

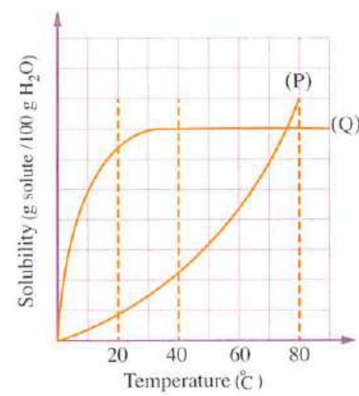


(1) Which of these substances its solubility increases significantly with increasing temperature ?

(2) At which temperature does the solubility of the substance (A) become the highest ?

(3) What is the mass of the substance (C) which is required to form a saturated solution when it dissolves in 100 g of H_2O at 70°C ?

26 **The opposite graph represents the solubility curves of two salts (P) and (Q) in water :**



(1) Which of the two salts is more soluble in water at 20°C ?

(2) Which of the two salts its solubility in water increases significantly on raising temperature above 20°C ?

(3) Mention one other factor – other than temperature – that can increase the solubilities of the two salts in water.

New types of questions ? Answered

Choosing two out of five choices questions :

1 **Which of the following dissolves in water forming a solution that has high ability to conduct electricity ?**

(a) Na_2CO_3
(b) C_2H_5OH
(c) HCl
(d) NH_4OH
(e) CH_3COOH

2 **The solubility of potassium nitrate salt in water is (30 g / 100 g H_2O) at 20°C**
All the following solutions of potassium nitrate salt are saturated at 20°C, except the two solutions produced from dissolving ....

(a) 15 g of the salt in 50 mL of water.
(b) 140 g of the salt in 500 mL of water.
(c) 35 g of the salt in 150 mL of water.
(d) 90 g of the salt in 300 mL of water.
(e) 60 g of the salt in 200 mL of water.

Concentrations of solutions

* The ratio of the amount of the solute to that of the solvent affects the concentration of solution.

* **Accordingly :**

- The solution in which the amount of the solute is large (yet still less than that of the solvent) is said to be a concentrated solution.
- The solution in which the amount of the solute is very small relative to that of the solvent is said to be a dilute solution.

The concentration of any solution decreases by increasing the amount of solvent

* Following, we will describe several methods for expressing the concentration, **which are :**

1. **Percentage.**
2. **Molarity.**
3. **Molality.**

1 Percentage (%)

* This method is suitable to express the concentrations of food and medicines.
* The percentage of a solution is expressed by two methods, according to the nature of the solute and that of the solvent, **as shown in the following :**

A Mass percentage (m/m)

It is the percentage of the mass of solute in 100 g of solution

B Volume percentage (V/V)

It is the percentage of the volume of solute in 100 mL of solution

law

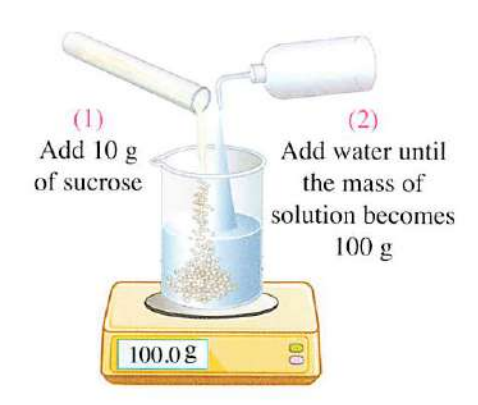
$$\text{Mass percentage (m/m)} = \frac{\text{Solute mass (g)}}{\text{Solution mass (g)}} \times 100\%$$

Solution mass = Solute mass + Solvent mass

$$\text{Volume percentage (V/V)} = \frac{\text{Solute volume (mL)}}{\text{Solution volume (mL)}} \times 100\%$$

Application

Preparation of an aqueous solution of sucrose 10% (m/m)



$$\therefore \text{Mass percentage} = \frac{10 \text{ g}}{100 \text{ g}} \times 100\%$$
$$= 10\%$$

"with neglecting the mass of the empty beaker"

Preparation of an aqueous solution of ethanol 25% (V/V)

$$\therefore \text{Volume percentage} = \frac{25 \text{ mL}}{100 \text{ mL}} \times 100\%$$
$$= 25\%$$

Note

The mass of 1 mL of the dilute aqueous solution equals approximately 1 g as the density of water is 1 g/mL

Worked Examples

1 What is the mass percentage (m/m) of the solution produced from dissolving 10 g of sucrose in 240 g of water ?

(a) 2%

(b) 4%

(c) 6%

(d) 8%

Idea of answering :

Mass of the solution = Mass of the solute + Mass of the solvent

$$= 10 + 240 = 250 \text{ g}$$

$$\text{Mass percentage} = \frac{\text{Mass of the solute (g)}}{\text{Mass of the solution (g)}} \times 100\%$$

$$= \frac{10}{250} \times 100\% = 4\%$$

Answer : The correct choice is (b)

---

2 What is the volume percentage (V/V) of the solution produced from the addition of 25 mL of ethanol to an amount of water to form 50 mL of the solution ?

(a) 25%

(b) 30%

(c) 35%

(d) 50%

Idea of answering :

$$\text{Volume percentage} = \frac{\text{Volume of the solute (mL)}}{\text{Volume of the solution (mL)}} \times 100\%$$

$$= \frac{25}{50} \times 100\% = 50\%$$

Answer : The correct choice is (d)

2 Molarity (M)

It is the number of moles of solute dissolved in one litre of solution

3 Molality (m)

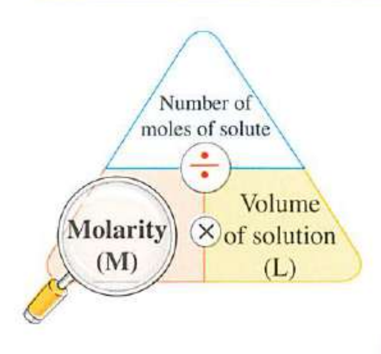
It is the number of moles of solute in one kilogram of solvent

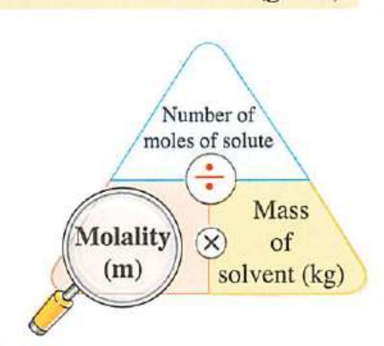
law

$$\text{Molarity (M)} = \frac{\text{Number of moles of solute (mol)}}{\text{Volume of solution (L)}}$$

$$\text{Molality (m)} = \frac{\text{Number of moles of solute (mol)}}{\text{Mass of solvent (kg)}}$$

$$\text{Number of moles of the solute (mol)} = \frac{\text{Mass of the solute (g)}}{\text{Molar mass of the solute (g/mol)}}$$





Measuring unit

The unit of molarity is (mol/L) or Molar (M)

The unit of molality is (mol/kg) or molal (m)

Worked Examples

Molarity

1 **What is the molar concentration of the solution which results from dissolving 85.5 g of table sugar $C_{12}H_{22}O_{11}$ in water to form a solution whose volume is 0.5 L ?**

[C = 12 , H = 1 , O = 16]

(a) 0.25 M
(b) 0.5 M
(c) 0.125 M
(d) 5.8×10^{-3} M

Idea of answering :

Molar mass of $C_{12}H_{22}O_{11} = (12 \times 12) + (22 \times 1) + (11 \times 16) = 342$ g/mol

$$\text{Number of moles of the solute} = \frac{\text{Mass of the solute (g)}}{\text{Molar mass of the solute (g/mol)}} = \frac{85.5}{342} = 0.25 \text{ mol}$$

$$\text{Molarity} = \frac{\text{Number of moles of the solute (mol)}}{\text{Volume of the solution (L)}} = \frac{0.25}{0.5} = 0.5 \text{ mol/L} = 0.5 \text{ M}$$

Answer : The correct choice is (b)

2 **Magnesium reacts with hydrochloric acid, according to the equation :**

$$Mg_{(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2(aq)} + H_{2(g)}$$

What is the volume of hydrochloric acid whose concentration is 1.5 M which is required to react completely with 17.28 g of magnesium (at STP) ? [Mg = 24]

(a) 0.96 L (b) 9600 mL (c) 3.5 L (d) 35.04 mL

Idea of answering :

$Mg_{(s)}$	$\xrightarrow[\text{with}]{\text{reacts}}$	$2HCl_{(aq)}$
24 g		2 mol
17.28 g		? mol

Number of reacted HCl moles $= \frac{17.28 \times 2}{24} = 1.44$ mol

$\because$ Molar concentration $= \frac{\text{Number of moles (mol)}}{\text{Volume (L)}}$

$\therefore$ Volume of HCl acid $= \frac{\text{Number of moles}}{\text{Molar concentration}} = \frac{1.44}{1.5} = 0.96$ L

Answer : The correct choice is (a)

---

3 **What are the concentrations of both the cations and the anions in 0.4 M $(NH_4)_2Cr_2O_7$ solution ?**

Choices	Concentration of the cations	Concentration of the anions
(a)	0.4 M	0.4 M
(b)	0.8 M	0.4 M
(c)	1 M	2 M
(d)	2 M	1 M

Idea of answering :

$$(NH_4)_2Cr_2O_7 \longrightarrow 2NH_4^+ + Cr_2O_7^{2-}$$

1 mol → 2 mol + 1 mol

$(NH_4)^+$ cations concentration = Number of cations moles × Molar concentration

$= 2 \times 0.4 = 0.8$ M

$(Cr_2O_7)^{2-}$ anions concentration = Number of anions moles × Molar concentration

$= 1 \times 0.4 = 0.4$ M

Answer : The correct choice is (b)

Molality

4 What is the molality of a solution prepared by dissolving 20 g of sodium hydroxide NaOH in 800 g of water ? [Na = 23 , O = 16 , H = 1]

(a) 0.256 m (b) 0.425 m (c) 0.532 m (d) 0.625 m

Idea of answering :

Molar mass of NaOH = 23 + 16 + 1 = 40 g/mol

$$\text{Number of moles of NaOH} = \frac{\text{Mass (g)}}{\text{Molar mass (g/mol)}} = \frac{20}{40} = 0.5 \text{ mol}$$

$$\text{Mass of the solvent (kg)} = \frac{800}{1000} = 0.8 \text{ kg}$$

$$\text{Molality} = \frac{\text{Number of moles of the solute (mol)}}{\text{Mass of the solvent (kg)}}$$

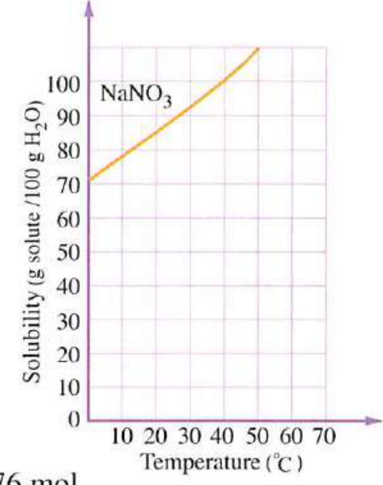
$$= \frac{0.5}{0.8} = 0.625 \text{ mol/kg} = 0.625 \text{ m}$$

Answer : The correct choice is (d)

---

5 The opposite graph represents the solubility curve of sodium nitrate salt $NaNO_3$ illustrate by the chemical calculations the molality of a saturated solution of $NaNO_3$ (at 40°C).

[Na = 23 , N = 14 , O = 16]



Answer :

Saturated solution of $NaNO_3$ (at 40°C) contains 100 g of solute in 100 g of water.

Molar mass of $NaNO_3$ = 23 + 14 + (3 × 16) = 85 g/mol

$$\text{Number of } NaNO_3 \text{ moles in its saturated solution} = \frac{100}{85} = 1.176 \text{ mol}$$

$$\text{Mass of solvent in saturated solution} = \frac{100}{1000} = 0.1 \text{ kg}$$

$$\text{Molal concentration} = \frac{\text{Number of solute moles}}{\text{Mass of solvent (kg)}}$$

$$= \frac{1.176}{0.1} = \mathbf{11.76 \text{ m}}$$

Test Yourself

Calculate the concentration of a solution produced from mixing 1 g of ethanol C_2H_5OH with 99 g of water H_2O, expressed by :

(1) **The mass percentage.** $[C_2H_5OH = 46\ g/mol]$

(2) **Molality.**

Answer :

(1) Mass of solution = ... + ... = 100 g

$\therefore$ The mass percentage = $\frac{\text{..............................}}{\text{Mass of the solution}} \times 100\% = \frac{1}{\text{......}} \times 100\% =$ ....

(2) Number of ethanol moles = $\frac{\text{Mass of ethanol}}{\text{Molar mass of ethanol}} = \frac{\text{..........}}{\text{..........}} =$ ....

$\therefore$ Mass of the solvent (kg) = $\frac{\text{......}}{1000} =$ ....

$\therefore$ Molality = $\frac{\text{Number of moles of the solute (mol)}}{\text{Mass of the solvent (kg)}} = \frac{\text{..........}}{\text{..........}} =$ **0.219 m**

Worked Example

Dilution of solutions

What is the concentration of the dilute acid produced from adding 200 mL of distilled water to 50 mL of HCl acid whose concentration is 0.2 M ?

ⓐ 0.01 M ⓑ 0.02 M ⓒ 0.03 M ⓓ 0.04 M

Idea of answering ① :

Molar concentration = $\frac{\text{Number of moles (mol)}}{\text{Volume (L)}}$

Number of moles of HCl acid = $0.2 \times \frac{50}{1000} = 0.01$ mol

Volume of dilute acid = $\frac{50 + 200}{1000} = 0.25$ L

$\therefore$ Concentration of dilute acid = $\frac{0.01}{0.25} = 0.04$ M

Idea of answering ② :

Volume of more concentrated acid (V_1) = 50 mL

Volume of dilute acid (V_2) = 200 + 50 = 250 mL

Concentration of more concentrated acid (M_1) = 0.2 M

Concentration of dilute acid (M_2) = ? M

$M_1V_1 = M_2V_2$

$\therefore$ Concentration of dilute acid (M_2) = $\frac{0.2 \times 50}{250} = 0.04$ M

Answer : The correct choice is ⓓ

Application

* **How to prepare an aqueous solution of sodium carbonate Na_2CO_3, its volume is 200 mL and its concentration is 0.2 M :** [Na = 23 , C = 12 , O = 16]

• **Calculate the mass of 0.2 M of Na_2CO_3 :**

Molar mass of Na_2CO_3 = $(2 \times 23) + 12 + (3 \times 16) = 106$ g/mol

No. of Na_2CO_3 moles = Molar concentration × Volume of the solution (L)

$$= 0.2 \times \frac{200}{1000} = 0.04 \text{ mol}$$

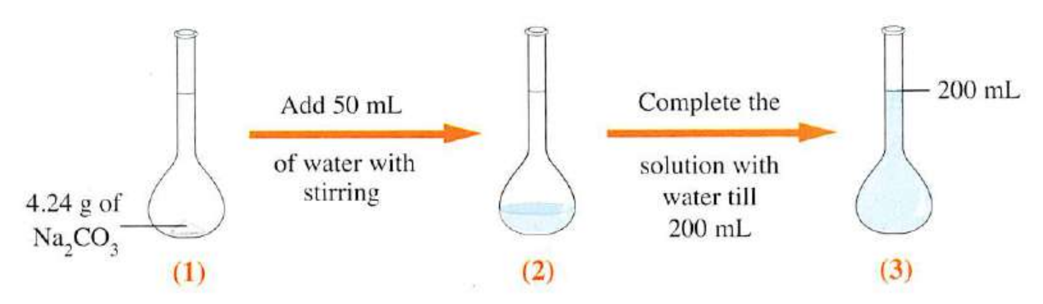
Required mass of Na_2CO_3 = Number of moles × Molar mass = $0.04 \times 106 = 4.24$ g

• **Then follow these steps :**

(1) Put 4.24 g of Na_2CO_3 in a flask.

(2) Add 50 mL of distilled water to the flask, with stirring till complete dissolution.

(3) Complete the solution by adding distilled water till 200 mL



Preliminary questions to remember the main concepts of the lesson

Answer them yourself

1 Choose the correct answer :

(1) When 0.5 mol of potassium hydroxide is dissolved in an amount of water to form 250 mL of a solution, the concentration will be ....

a. 2 M
b. 2 m
c. 0.08 g/L
d. 0.08 mol/L

(2) What is the volume of NaCl solution which contains 0.06 mol of the solute and its concentration = 0.3 M ?

a. 0.018 L
b. 0.2 L
c. 0.5 L
d. 5 L

(3) The molal concentration of a solution is expressed by ....

a. mol/L
b. g/eq.L
c. g/L
d. mol/kg

(4) Molal solution contains 1 mol of the solute in ....

a. 22.4 L of the solution.
b. 1000 g of the solvent.
c. 1 L of the solution.
d. 1 L of the solvent.

(5) What is the molality of the solution produced from dissolving 5.1 mol of KNO_3 in 4.47 kg of water ?

a. 0.315 m
b. 1.02 m
c. 0.779 m
d. 1.14 m

2 Miscellaneous problems :

(1) Calculate the (m/m) percentage of a solution formed by dissolving 10 g of sucrose in 240 g of water.

(2) Calculate the molarity of a solution whose volume is 3 L and contains 0.5 mol of silver nitrate.

(3) Calculate the molarity of 200 mL of solution formed by dissolving 20 g of NaOH in water. [Na = 23 , O = 16 , H = 1]

(4) 53 g of sodium carbonate are dissolved in 1 kg of water.
What is the molality of this solution ? [Na = 23 , C = 12 , O = 16]

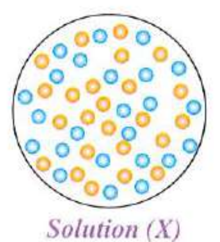
Open book questions

Answered

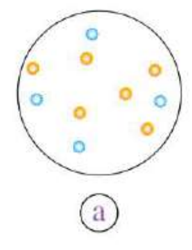
Multiple choice questions

Concentrations of solutions

1 The opposite figure represents the particles in a concentrated electrolytic solution (X).
Which of the following expresses the dilute solution of the solution (X) ?
"Drawing molecules of water is neglected for simplification".



Solution (X)



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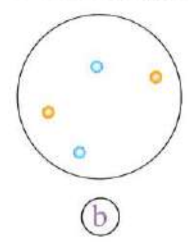

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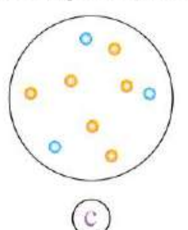

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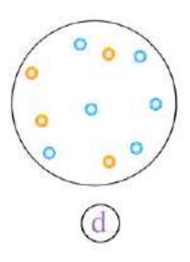
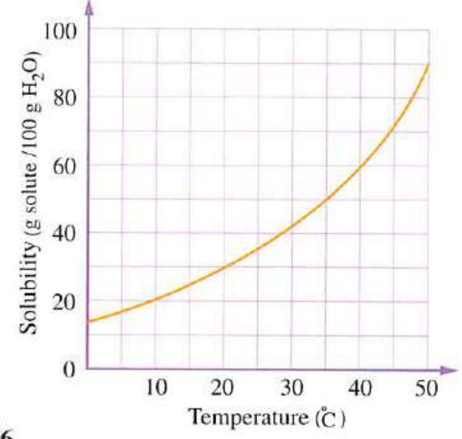


ⓓ

Percentage (m/m)

2 In the opposite graph.
What is the mass percentage concentration of the solution at $20^\circ C$?

ⓐ 20%
ⓑ 23.1%
ⓒ 42.8%
ⓓ 30%



3 What is the mass of the solution of glucose $C_6H_{12}O_6$ whose concentration is 10% and contains 1 mol of the solute ? [C = 12 , H = 1 , O = 16]

ⓐ 1 kg ⓑ 1.8 kg
ⓒ 200 g ⓓ 900 g

4 What is the concentration of sodium hydroxide solution whose volume is 2.5 L and contains 0.4 g of NaOH ?

ⓐ 16% ⓑ 1.6%
ⓒ 0.16% ⓓ 0.016%

5 What is the concentration percentage of an aqueous solution whose one liter contains one mole of sucrose $C_{12}H_{22}O_{11}$? [C = 12 , H = 1 , O = 16]

(a) 6.84% (b) 10%

(c) 34.2% (d) 100%

6 Which of the following shows the mass of each of the solute and the solvent in potassium chloride solution its mass is 250 g and its concentration is 5% ?

Choices	Mass of the solute	Mass of the solvent
(a)	12.5 g	250 g
(b)	25 g	225 g
(c)	12.5 g	237.5 g
(d)	5 g	250 g

7 Solution (A) is formed from mixing 300 g of solution (B) whose concentration is 25% with 400 g of solution (C) whose concentration is 40%. What is the percentage of each of the solute and the solvent in solution (A) ?

Choices	Percentage of solute	Percentage of solvent
(a)	23%	77%
(b)	12.5%	87.5%
(c)	33.6%	66.4%
(d)	50%	50%

Percentage (V/V)

8 The volume percentage of oxygen in atmospheric air is 21%
What is the number of moles of oxygen in 1 L of air (at STP) ?

(a) 0.186 mol (b) 0.0094 mol

(c) 0.21 mol (d) 2.1 mol

Molarity

9 58.5 g of sodium chloride are dissolved in an amount of water to form 0.5 L of a solution.
What is the concentration of this solution ? [Na = 23 , Cl = 35.5]

(a) 0.25 M (b) 0.5 M

(c) 1 M (d) 2 M

10 Which of the following solutions contains the highest number of moles of the solute ?

(a) 10 mL of 0.5 mol/L NaCl solution.

(b) 20 mL of 0.4 mol/L NaCl solution.

(c) 30 mL of 0.3 mol/L NaCl solution.

(d) 40 mL of 0.2 mol/L NaCl solution.

11 What is the mass of $Na_2S_2O_3.5H_2O$ which is required to form 200 mL of an aqueous solution with concentration 0.1 mol/L ? [Na = 23 , S = 32 , O = 16 , H = 1]

(a) 3.16 g
(b) 4.96 g
(c) 24.8 g
(d) 31.6 g

12 The mass of sodium carbonate which is required to prepare 500 mL of 0.5 M solution equals .... [Na = 23 , C = 12 , O = 16]

(a) 10000 g
(b) 106 g
(c) 40 g
(d) 26.5 g

13 An aqueous solution of sucrose (its molar mass = 342 g/mol) contains 123 g of the solute and its molar concentration = 0.55 M

What is the volume of this solution ?

(a) 66 mL
(b) 220 mL
(c) 340 mL
(d) 654 mL

14 On dissolving 14 g of a substance (X) in an amount of water, a solution is formed its volume = 2000 mL and its concentration = 0.25 mol/L

What is the molar mass of the substance (X) ?

(a) 14 g/mol
(b) 28 g/mol
(c) 56 g/mol
(d) 70 g/mol

15 What is the concentration of the chloride ions in 1 L of a solution in which 2.08 g of $BaCl_2$ salt are dissolved ? [Ba = 137 , Cl = 35.5]

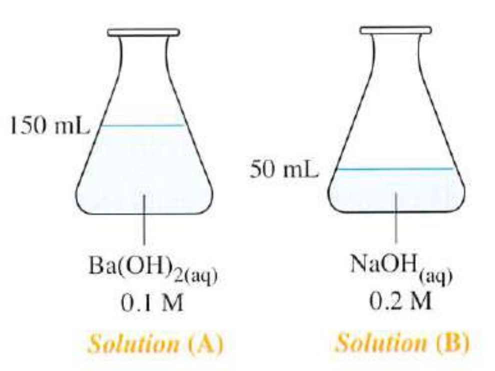
(a) 0.01 M
(b) 0.012 M
(c) 0.02 M
(d) 2.08 M

16 200 mL of a solution contain 0.04 mol of $(NH_4)_2Ni(SO_4)_2.6H_2O$

What is the concentration of ammonium ions NH_4^+ in it ?

(a) 0.0004 M
(b) 0.008 M
(c) 0.2 M
(d) 0.4 M

17 Which of the following statements represents the relation between the two solutions in the opposite figure ?



Number of OH^- moles in solution (A) is ....

(a) half its number in solution (B).
(b) equal to its number in solution (B).
(c) double its number in solution (B).
(d) triple its number in solution (B).

18 The concentration percentage of a molar solution of sulphuric acid H_2SO_4 equals .... [H = 1 , S = 32 , O = 16]

(a) 0.098% (b) 0.98%
(c) 9.8% (d) 98%

Molarity of solutions in chemical reactions

19 What is the mass of magnesium oxide which is required to react completely with 40 mL of hydrochloric acid whose concentration is 1 mol/L ? [Mg = 24 , O = 16]

(a) 0.8 g (b) 1.6 g
(c) 2.4 g (d) 3.2 g

20 According to the reaction : $Na_2SO_{4(aq)} + BaCl_{2(aq)} \longrightarrow 2NaCl_{(aq)} + BaSO_{4(s)}$

What is the molarity of Na_2SO_4 solution when 250 mL of it are required to precipitate 5.28 g of barium sulphate ? [Ba = 137 , S = 32 , O = 16 , Na = 23]

(a) 0.09 M (b) 0.9 M
(c) 0.0227 M (d) 0.227 M

21 According to the reaction : $4FeCl_{2(aq)} + 3O_{2(g)} \longrightarrow 2Fe_2O_{3(s)} + 4Cl_{2(g)}$

What is the volume of 0.76 M solution of $FeCl_2$ which reacts completely with 6.36×10^{21} molecules of oxygen ?

(a) 5.26×10^3 mL (b) 10.7 mL
(c) 10.4 mL (d) 18.5 mL

22 On mixing 4 mL of 0.5 mol/L copper (II) sulphate solution with 4 mL of 0.5 mol/L sodium hydroxide solution, the substances which remain after the end of the reaction are ....

(a) $Cu(OH)_{2(aq)}$ and $NaOH_{(aq)}$
(b) $Cu(OH)_{2(s)}$, $Na_2SO_{4(aq)}$ and $CuSO_{4(aq)}$
(c) $Cu(OH)_{2(aq)}$, $Na_2SO_{4(aq)}$ and $CuSO_{4(aq)}$
(d) $Cu(OH)_{2(s)}$ and $NaOH_{(aq)}$

23 What is the concentration of sulphuric acid which 25 mL of it react completely with 36.2 mL of 0.225 M sodium hydroxide solution ?

(a) $\frac{36.2 \times 0.225}{25}$ M
(b) $\frac{2 \times 36.2 \times 0.225}{25}$ M
(c) $\frac{36.2 \times 0.225}{2 \times 25}$ M
(d) $\frac{25}{2 \times 36.2 \times 0.225}$ M

Molality

24 What is the molal concentration of the solution which results from dissolving 6.44 g of naphthalene ($C_{10}H_8$) in 80 g of benzene ? [C = 12 , H = 1]

(a) 0.629 m
(b) 0.8 m
(c) 1.13 m
(d) 80.4 m

25 An aqueous solution of sodium chloride (its molar mass = 58.5 g/mol), its molal concentration = 3.14 m, and the mass of water in it = 2314 g

What is the mass of NaCl in this solution ?

(a) 124.3 g
(b) 255.6 g
(c) 425 g
(d) 726.6 g

26 What is the volume of water which is required to be added to 328 g of NaOH to form a solution whose concentration is 1.35 m ? [Na = 23 , O = 16 , H = 1]

(a) 6.07 L
(b) 7.44 L
(c) 11.1 L
(d) 14.5 L

27 On dissolving 20 g of a salt in an amount of water, a solution is formed its mass = 280 g and its concentration is 0.2 m

What is the mass of 1 mol of this salt ?

(a) 260 g/mol
(b) 283 g/mol
(c) 342.8 g/mol
(d) 384.6 g/mol

28 If the solubility of sodium chloride salt in water = 36 g/100 g H_2O (at 20°C)

What is the molality of the saturated solution which is formed at the same temperature ? [Na = 23 , Cl = 35.5]

(a) 6.15 m
(b) 5.8 m
(c) 6.15×10^{-3} m
(d) 5.8×10^{-3} m

Dilution of solutions

29 **What is the concentration of the solution which is produced from mixing 75 mL of 0.05 M HCl solution with 25 mL of 3 M HCl solution ?**

(a) 0.375 M (b) 0.393 M
(c) 0.75 M (d) 0.7875 M

30 **5 mol/L sulphuric acid has been diluted from 1 L to 10 L**

What is the molar concentration of the dilute acid ?

(a) 0.1 M (b) 0.5 M
(c) 1 M (d) 5 M

31 **What is the volume of water which is required to be added to 500 mL of a molar solution of table salt to form 0.1 M solution of it ?**

(a) 100 mL (b) 1000 mL
(c) 4.5 L (d) 5 L

32 **10 mL of 6 M hydrochloric acid were diluted with water until the concentration became 0.5 M**

What is the volume of the added water ?

(a) 50 mL (b) 110 mL
(c) 120 mL (d) 290 mL

Essay questions

The percentage

33 **Calculate the percentage (m/m)** of the solution which results from adding 0.5 mol of caustic soda NaOH to a given volume of water until the solution mass becomes 80 g

[Na = 23 , O = 16 , H = 1]

34 **Calculate the mass** of silver nitrate solution whose mass percentage is 15.5% and contains 25.2 g of silver nitrate.

35 **Calculate the percentage (V/V)** of the solution which is formed by dissolving 15 mL of oil in an amount of gasoline to yield 50 mL of the solution.

Molarity

36 Sulphuric acid ionizes in water according to the following equation :

$$H_2SO_{4(aq)} \longrightarrow 2H^+_{(aq)} + SO^{2-}_{4(aq)}$$

Calculate the concentration of each of $H^+_{(aq)}$, $SO^{2-}_{4(aq)}$ ions in 0.3 M solution.

37 **Calculate the volume** of 0.14 M sodium chloride solution which contains 1 mg of NaCl

[Na = 23 , Cl = 35.5]

Molarity of solutions in chemical reactions

38 **20 mL of 0.25 M lead (II) nitrate solution are added to an excess of potassium iodide solution whose concentration = 0.5 M , thus a yellow precipitate of lead (II) iodide is formed :** [Pb = 207 , I = 126.9]

(1) Write the ionic equation which represents this reaction.

(2) Calculate the mass of the formed yellow precipitate.

39 **On the reaction of magnesium with dilute hydrochloric acid, hydrogen gas evolves :**

(1) Calculate the volume of 1.5 M hydrochloric acid which is required to react completely with 20 g of magnesium. [Mg = 24]

(2) Calculate the volume of hydrogen gas produced (at STP).

Molality

40 **Calculate the mass** of glucose $C_6H_{12}O_6$ which is required to be dissolved in 563 g of ethanol C_2H_5OH to form a solution with concentration 2.4×10^{-2} m [C = 12 , H = 1 , O = 16]

41 **Calculate the molal concentration** of a solution prepared by dissolving 5.6 g of KOH in 500 mL of water. [K = 39 , O = 16 , H = 1]

Dilution of solutions

42 200 mL of water are added to 50 mL of 0.2 M HCl acid.

Calculate the molar concentration of the produced dilute solution.

New types of questions ? Answered

Choosing two out of five choices questions :

1 Which of the following is a solution its volume percentage (V/V) is 25% ?

Solution	Volume of solute (mL)	Volume of solvent (mL)
A	20	100
B	15	65
C	25	75
D	30	90
E	6	14

(a) A

(b) B

(c) C

(d) D

(e) E

2 Which of these solutions contains the same number of moles of sodium hydroxide ?

(a) 1 mL of 0.1 M solution.

(b) 10 mL of 0.1 M solution.

(c) 100 mL of 1 M solution.

(d) 1000 mL of 1 M solution.

(e) 1000 mL of 0.1 M solution.

3 A liter of 0.25 M solution of caustic soda NaOH contains each of the following of NaOH, except .... [Na = 23 , O = 16 , H = 1]

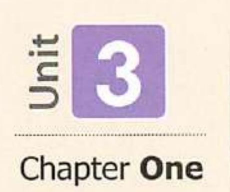
(a) 10 g

(b) 40 g

(c) 0.25 mol

(d) 1.505×10^{23} molecules.

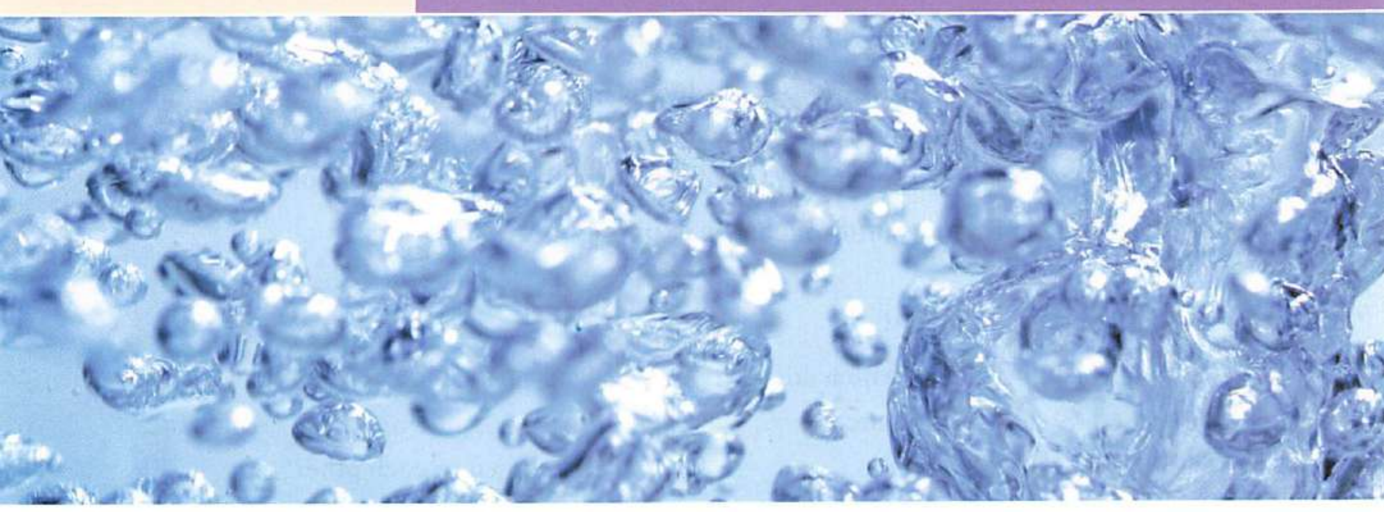
(e) 6.02×10^{23} molecules.



Lesson 3

From Colligative properties of solutions

Until Before mixtures properties



Colligative properties of solutions

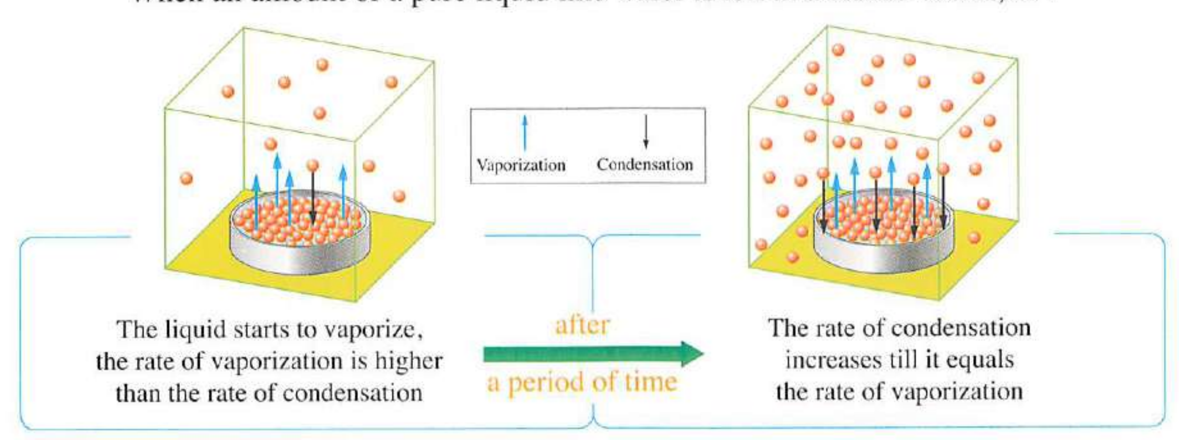
- The properties of solutions differ from the properties of the pure solvents forming them after dissolving nonvolatile substances in these solvents at the same conditions, these new properties are called **colligative (collective) properties of solutions** *which depend only on the number of solute particles per unit volume of solution.*

Among these properties are :

1. **Vapor pressure depression.**
2. **Boiling point elevation.**
3. **Freezing point depression.**

1 Vapor pressure depression

When an amount of a pure liquid like water is left in a closed vessel, so :



- The system (water - water vapour) in which (vaporization rate = condensation rate) is described to be at a state of dynamic equilibrium, the vapour causes a pressure on the surface of the liquid known as **vapor pressure** *which is the pressure that affects the liquid surface, when the vapor is at dynamic equilibrium with its liquid inside a closed container at constant temperature and pressure (at the standard conditions).*

For illustration

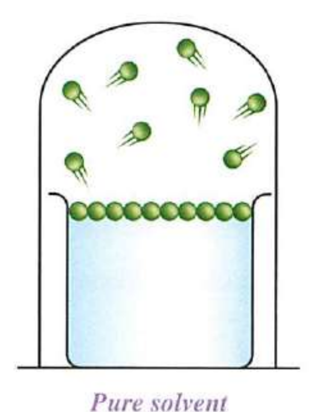
Vapour pressure of the pure liquid or the solution is not affected by :

- Change in the external pressure.
- Increasing or decreasing the amount of the liquid.

The depression of the vapor pressure of a pure solvent when a nonvolatile solute is dissolved in it to form a solution can be explained as follows :

Pure solvent

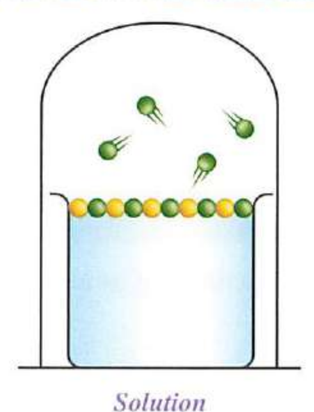
- The surface molecules which are exposed to vaporization are the solvent molecules only.
- The forces that have to be overcome are the attraction forces between the solvent molecules with each other.



Pure solvent

Solution

- The surface molecules are the solvent and the solute molecules which are combined to each other.
- The number of solvent molecules which are exposed to vaporization decreases.
- The forces that have to be overcome are the attraction forces between the solvent and the solute molecules.

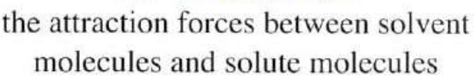


Solution

and since that

the attraction forces among solvent molecules

are weaker than



the attraction forces between solvent molecules and solute molecules

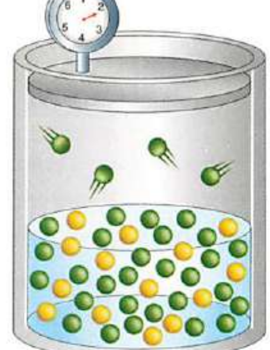
So

the vapour pressure of a pure solvent

is higher than

the vapour pressure of the solution

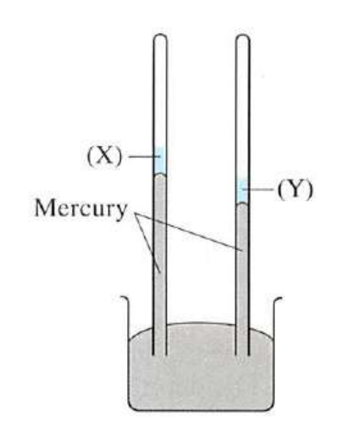
Vapour pressure of a pure solvent



Vapour pressure of a solution

Worked Example

The opposite figure shows a container contains mercury, and two inverted tubes are placed in it, above the surface of one of them a small volume of pure water, and above the other the same volume of 10 m NaCl solution.
Which of the following represents (X) or (Y) correctly ?



(a) (X) represents water, as its vapour pressure is higher than that of the salty solution.

(b) (X) represents the salty solution, as its vapour pressure is lower than that of water.

(c) (Y) represents water, as its vapour pressure is lower than that of the salty solution.

(d) (Y) represents the salty solution, as its vapour pressure is higher than that of water.

Idea of answering :

∵ The length of the column of mercury under the substance (X) is longer than that under the substance (Y).

∴ The vapour pressure in case of the substance (X) is lower than that in case of the substance (Y).

∵ The vapour pressure of the solution is lower than that of its pure solvent.

∴ (X) represents the salty solution and (Y) represents water.

Answer : The correct choice is (b)

* The depression of the vapour pressure of the solution is directly proportional to the number of moles (ions or molecules) of the solute in this solution, where **the depression** of the vapour pressure increases (**i.e.** the vapour pressure decreases) :
  - In the nonelectrolytic solution : By increasing the number of moles of the solute molecules in it.
  - In the electrolytic solution : By increasing the number of moles of the solute ions in it.

* The vapour pressure of the solution does not depend on the type of the solution.

Worked Example

Which of the following substances has the highest effect on the depression of the vapour pressure of water when 1 mol of it is dissolved in 1 kg of water ?

(a) $C_2H_5OH_{(l)}$

(b) $Al(NO_3)_{3(s)}$

(c) $NaCl_{(s)}$

(d) $CuCl_{2(s)}$

Idea of answering :

* The depression of the vapour pressure increases by increasing the number of moles (of ions or molecules) of the solute.
* The correct choice is that which when ionizes, it yields the highest number of moles of ions or molecules.

(a) $C_2H_5OH_{(l)} \xrightarrow{\text{water}} C_2H_5OH_{(aq)}$

1 mol — 1 mol of molecules

(b) $Al(NO_3)_{3(s)} \xrightarrow{\text{water}} Al^{3+}_{(aq)} + 3NO^-_{3(aq)}$

1 mol — 4 mol of ions

(c) $NaCl_{(s)} \xrightarrow{\text{water}} Na^+_{(aq)} + Cl^-_{(aq)}$

1 mol — 2 mol of ions

(d) $CuCl_{2(s)} \xrightarrow{\text{water}} Cu^{2+}_{(aq)} + 2Cl^-_{(aq)}$

1 mol — 3 mol of ions

∴ The depression in the vapour pressure of water when 1 mol of $Al(NO_3)_3$ dissolves in it is the greatest.

Answer : The correct choice is (b)

2 Boiling point elevation

* On raising the temperature of a liquid placed in a closed container, the rate of its vaporization increases, and hence its vapour pressure increases till it becomes equal to the normal atmospheric pressure, the liquid starts to boil and in this case the boiling point of the liquid is called the natural (normal) boiling point.
* **The natural (normal) boiling point** *is the temperature at which the vapor pressure of the liquid equals the atmospheric pressure.*

* **Measured boiling point** *is the temperature at which the vapor pressure of the liquid equals the pressure exerted or acted on it.*

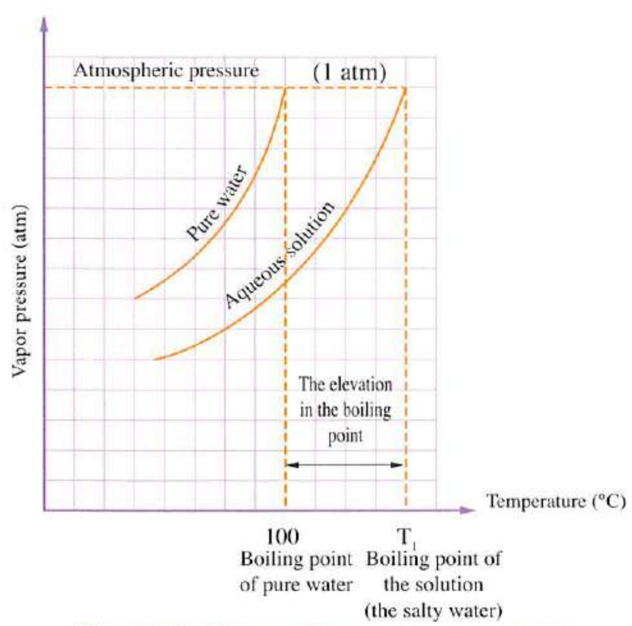
* The boiling point can be used as an indicator for the purity of the liquids, because the measured boiling point of the pure liquid equals its normal boiling point.

* When the pressure exerted on pure water or any other pure liquid is lower than the normal atmospheric pressure (1 atm), the measured boiling point becomes less than the normal boiling point.

* The boiling point of solution **is always higher than** the boiling point of pure solvent which forms it, because the vapor pressure of solution is lower than the vapor pressure of pure solvent which forms it, the solution needs more energy until its vapor pressure equals the atmospheric pressure to boil.

Application

* **The difference of the boiling point of the salty water from that of the pure water.**
   - Pure water boils at 100°C at normal atmospheric pressure (1 atm). However, the addition of a certain quantity of salt in water decreases its vapour pressure, and consequently elevates the boiling point of the solution (the salty water) to T_1 , thus the boiling point of the solution is always higher than that of pure water.



The relation between the vapor pressure (atm) and both the boiling points of water and the solution (°C)

Elevation of the boiling point increases :

- In the nonelectrolytic solution : By increasing the number of moles of the solute molecules.
- In the electrolytic solution : By increasing the number of moles of the solute ions.

Worked Examples

1 Which of the following solutions which have equal molar concentrations has the highest boiling point ?

(a) HI solution.

(b) $(NH_4)_3PO_4$ solution.

(c) K_2CO_3 solution.

(d) NaI solution.

Idea of answering :

* The boiling point of the solution increases by increasing the number of the dissolved moles in it.
* The correct choice is the solution in which the number of the dissolved moles is the highest.

$$HI_{(l)} \xrightarrow{water} H^+_{(aq)} + I^-_{(aq)}$$

1 mol　　　　2 mol of ions

$$(NH_4)_3PO_{4(aq)} \xrightarrow{water} 3NH^+_{4(aq)} + PO^{3-}_{4(aq)}$$

1 mol　　　　4 mol of ions

$$K_2CO_{3(s)} \xrightarrow{water} 2K^+_{(aq)} + CO^{2-}_{3(aq)}$$

1 mol　　　　3 mol of ions

$$NaI_{(s)} \xrightarrow{water} Na^+_{(aq)} + I^-_{(aq)}$$

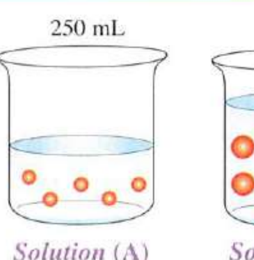
1 mol　　　　2 mol of ions

∴ The boiling point of $(NH_4)_3PO_4$ solution is the highest.

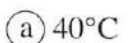
Answer : The correct choice is (b)

---

2 The two opposite figures show two solutions (A) and (B), each ball in them represents 0.5 mol of the solute ions, if the boiling point of solution (A) is 80°C, then the boiling point of solution (B) could be ....



Solution (A)　　Solution (B)


(a) 40°C　　(b) 60°C

(c) 80°C　　(d) 100°C

Idea of answering :

Number of moles of the solute ions in solution (A) = $5 \times 0.5 = 2.5$ mol

Concentration of solution (A) = $\frac{2.5}{0.25} = 10$ mol/L

Number of moles of the solute ions in solution (B) = $10 \times 0.5 = 5$ mol

Concentration of solution (B) = $\frac{5}{0.5} = 10$ mol/L

∴ Both solutions are equally concentrated.

∴ They have the same boiling point.

Answer : The correct choice is (c)

Test Yourself

Which of the following solutions that are produced from dissolving 3 g of the solute in 100 g of water has higher boiling point ?

(a) RbF (104.5 g/mol).

(b) $HOCH_2CH(OH)CH_2OH$ (92 g/mol).

(c) $Ti(NO_3)_3$ (390.4 g/mol).

(d) $AlCl_3$ (133.5 g/mol).

Idea of answering :

* The molality of each solution, as well as the number of the moles of the ions produced in each solution are calculated as in the following table :

Choices	Molality	Ionization equation	No. of moles of the produced ions
(a)	$\frac{3 \div 104.5}{100 \div 1000} = 0.29$ m	$RbF_{(s)} \xrightarrow{water} Rb^+_{(aq)} + F^-_{(aq)}$	$2 \times 0.29 = 0.58$ mol ion
(b)	....	....	....
(c)	....	....	....
(d)	....	....	....

∵ The boiling point of a solution .... by increasing the number of the ions dissolved in it.

∴ The solution .... has higher boiling point than the others.

Answer : The correct choice is ....

3 Freezing point depression

The freezing point of solution is always less than the freezing point of pure solvent which forms it, as the attraction forces between the solvent molecules and the solute molecules in the solution hinders the conversion of the solvent from liquid state to solid state (crystals), hence it is required to decrease the temperature of the solution to less than the freezing point of the pure solvent, so that the solute crystals are separated from the solvent crystals.

Application

Adding salt to snow-covered roads in cold places, to prevent cars from slipping and decrease the number of accidents where salt dissolves in water forming a solution, which freezes at a temperature lower than the freezing point of pure water, so the amount of snow will decrease.

Adding salt to snow-covered roads

Freezing point depression is **directly proportional to** the number of dissolved solute particles in solution, where the depression of the freezing point of a solution increases :

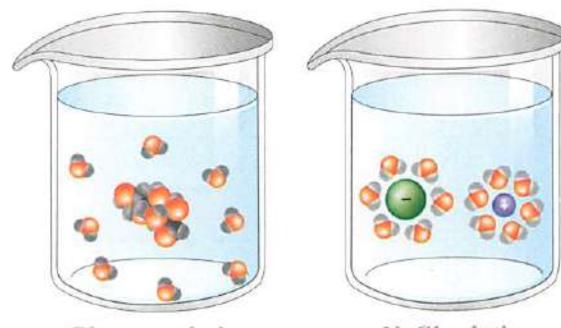
- In the nonelectrolytic solution: By increasing the number of moles of the solute molecules in it.
- In the electrolytic solution: By increasing the number of moles of the solute ions in it.

Application

The depression of the freezing point of sodium chloride solution is double that of the freezing point of glucose solution which has the same molal concentration.

$$NaCl_{(s)} \xrightarrow{\text{water}} Na^{+}_{(aq)} + Cl^{-}_{(aq)}$$

1 mol → 2 mol of ions



Glucose solution *NaCl solution*

(1 m concentration)

As the dissolution of 1 mol of glucose sugar in water forms 1 mol of its molecules in the solution, while dissolving 1 mol of NaCl in water forms 2 mol of ions in the solution, which leads to doubling the depression of the freezing point.

When 1 mol of any nonelectrolyte such as glucose is dissolved in 1 kg of water, the resulting solution freezes at (–1.86°C).

while the substance which is dissociated into ions in water (electrolyte), the freezing point of its solution is calculated using the relation :

The freezing point of electrolytic solution = Number of moles of ions in the solution × (–1.86°C)

Worked Example

Calculate the freezing point of the solution that contains 1 mol of calcium chloride $CaCl_2$ in 1000 g of water.

Answer :

$$CaCl_{2(s)} \xrightarrow{H_2O_{(l)}} Ca^{2+}_{(aq)} + 2Cl^{-}_{(aq)}$$

1 mol → 3 mol of ions

The freezing point of an electrolytic solution = No. of moles of ions × (– 1.86°C)

= 3 × (–1.86) = **–5.58°C**

Test Yourself

Which of the following solutions has a freezing point which equals that of an aqueous solution of $C_6H_{12}O_6$ whose concentration is 0.4 m ?

(a) 0.8 m CH_3COOH

(b) 0.4 m KCl

(c) 0.2 m Na_2SO_4

(d) 0.1 m Na_3PO_4

Idea of answering :

Molal concentration = $\frac{\text{..................}}{\text{..................}}$

Assuming that the mass of the solvent in all solutions is 1 kg

∴ Molal concentration = ...

∴ Number of $C_6H_{12}O_6$ moles = 0.4 mol

* The number of moles of ions of each solute is calculated.
* The correct choice is the solute which has the same number of moles of $C_6H_{12}O_6$

(a) 0.8 × 2 = 1.6 mol

(b) ....

(c) ....

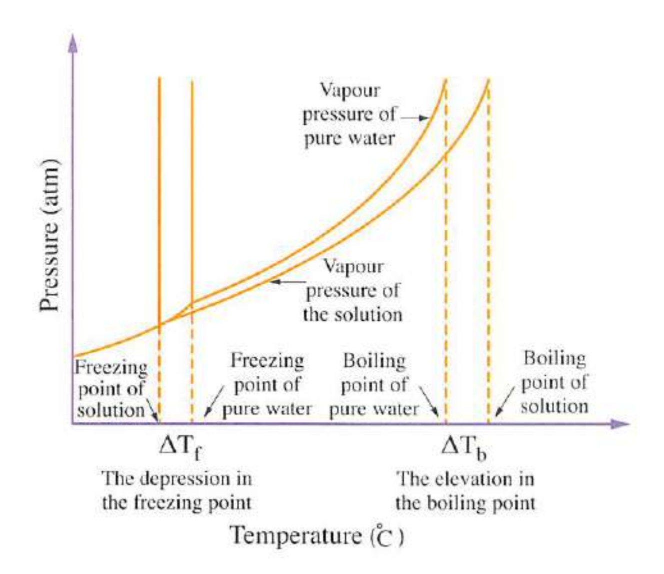
(d) ....

Answer : The correct choice is (d)

★ Comparison between the solution and the pure solvent "in terms of : colligative properties"

Colligative properties	Solution		Its pure solvent
Vapour pressure	Vapour pressure of solution	<	Vapour pressure of pure solvent
Boiling point	Boiling point of solution	>	Boiling point of pure solvent
Freezing point	Freezing point of solution	<	Freezing point of pure solvent

* The graphical figure shows the change in the vapour pressure and both boiling and freezing points of pure water when a nonvolatile substance is added to it to form a solution :



Preliminary questions to remember the main concepts of the lesson

Answer them yourself

1 Choose the correct answer :

(1) All the following are among the colligative properties of solutions, except ....

a. elevation of the boiling point.

b. surface tension.

c. depression of the freezing point.

d. depression of the vapor pressure.

(2) When the vapor pressure of pure liquid is equal to the atmospheric pressure, the measured boiling point is ....

a. higher than the natural boiling point.

b. equal to the natural boiling point.

c. lower than the natural boiling point.

(3) Which of the following statements is correct ?

a. The boiling point of salty water is lower than that of pure water.

b. The boiling point of salty water is equal to that of pure water.

c. The boiling point of salty water is higher than that of pure water.

(4) Solution (A) of glucose and solution (B) of table salt, both have the same concentration.

Which of the following represents the relation between the boiling points of these two solutions ?

a. Boiling point of solution (B) $\geq$ Boiling point of solution (A).

b. Boiling point of solution (B) > Boiling point of solution (A).

c. Boiling point of solution (B) < Boiling point of solution (A).

d. Boiling point of solution (B) = Boiling point of solution (A).

(5) Which of the following solutions has the highest boiling point ?

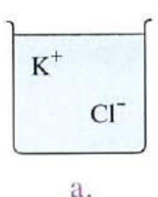
a. 1 M KNO_3

b. 2 M KNO_3

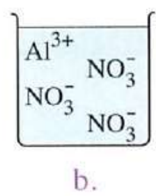
c. 1 M $Ca(NO_3)_2$

d. 2 M $Ca(NO_3)_2$

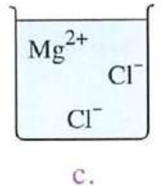
(6) Which of the following solutions whose molar concentration is 1 M has the lowest freezing point ?



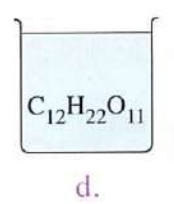
a.



b.



c.



d.

2 Give reasons for :

(1) The vapor pressure of a solution is lower than the vapor pressure of its pure solvent.

(2) The boiling point of a solution is higher than that of its pure solvent.

(3) The boiling point of sodium carbonate solution is higher than the boiling point of sodium chloride solution with the same molal concentration.

(4) The freezing point of a solution is lower than that of its pure solvent.

(5) Salt is sprinkled on snow-covered roads in cold places.

Open book questions

Answered

Multiple choice questions

Depression of vapour pressure of the solution

1 **Which of the following salts has the highest effect on the depression of the vapour pressure of water when 1 mol of it is dissolved in one liter of water ?**

(a) KCl

(b) $MgCl_2$

(c) $C_6H_{12}O_6$

(d) KBr

2 **Which of the following solutions - all have the same molal concentration - has the lowest vapour pressure ?**

(a) Acetic acid solution.

(b) Potassium chloride solution.

(c) Sodium phosphate solution.

(d) Sodium sulphate solution.

3 **An amount of oil is dissolved in a known mass of pure benzene, so if the vapour pressure of benzene is 750 mm Hg What is the vapour pressure of the solution ?**

(a) 760 mm Hg

(b) 750 mm Hg

(c) 731.5 mm Hg

(d) 75 mm Hg

4 **Hydrogen gas is collected when it is prepared in lab by downward displacement of water, the pressure produced on the surface of water is the sum of the pressure of hydrogen gas and the pressure of ....**

(a) oxygen gas.

(b) water vapour.

(c) hydrogen dissolved in water.

(d) the noble gases found in air.

5 Two equal volumes with different concentrations of a nonelectrolytic solution had been placed in two containers (A) and (B) as in figure (1), and after some time (at STP), these volumes were changed as in figure (2) :

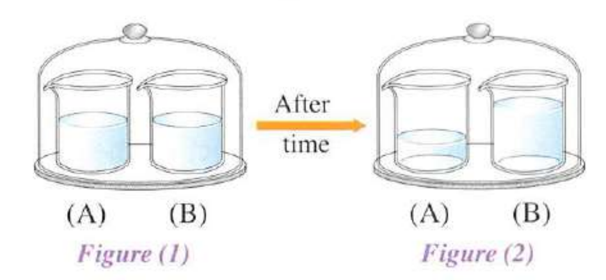


Figure (1) *Figure (2)*

Which of the following represents the concentrations of both solutions as well as their vapour pressures in the case illustrated in figure (2) ?

Choices	Concentrations of the solutions	Vapour pressures of the solutions
(a)	A = B	A = B
(b)	A = B	A < B
(c)	A > B	A = B
(d)	A < B	A > B

Elevation of boiling point of the solution

6 In the opposite table.

What is the liquid whose vapour pressure is the highest at the same temperature ?

Compound	Boiling point (°C)
Water	100
Acetone	56
Acetaldehyde	31
Acetic acid	118

(a) Water.

(b) Acetone.

(c) Acetaldehyde.

(d) Acetic acid.

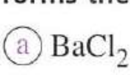
7 Which of the following aqueous solutions - all have the same molal concentration - has the highest boiling point ?

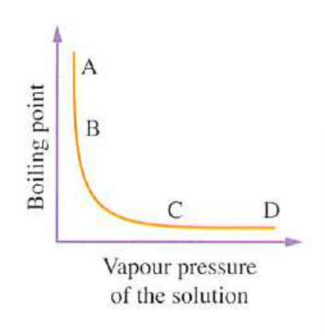
(a) $CaCl_{2(aq)}$

(b) $NaNO_{3(aq)}$

(c) $CH_3COOH_{(aq)}$

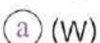
(d) $Al(NO_3)_{3(aq)}$

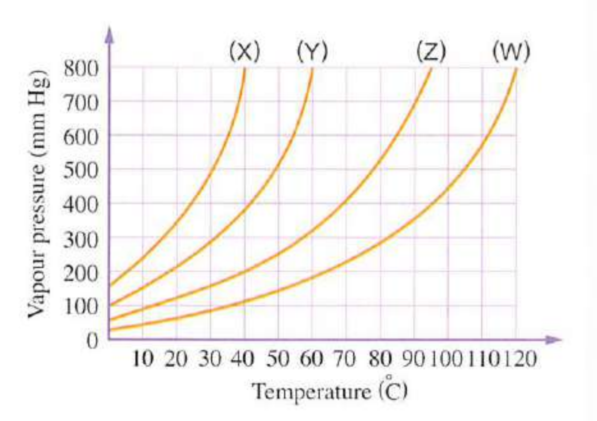
 The opposite figure represents the relation between the boiling points and the vapour pressures of four different solutions. Which of the following compounds forms the molal solution which is referred to by the letter (A) ?



(a) $BaCl_2$ (b) $C_6H_{12}O_6$

(c) $C_{12}H_{22}O_{11}$ (d) NaCl

 The graph represents the relation between the vapour pressure of 4 pure liquids (W), (X), (Y) and (Z) at different temperatures. Which of these liquids has the highest boiling point ?



(a) (W)

(b) (X)

(c) (Y)

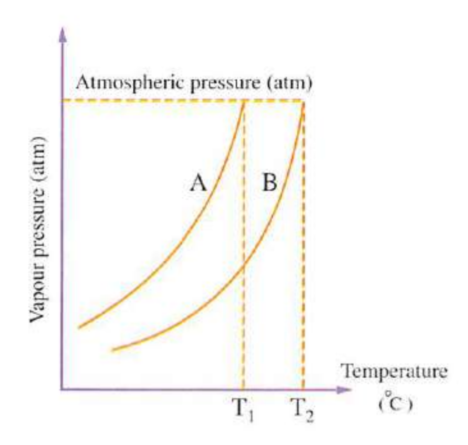
(d) (Z)

10 If the boiling point of one mole of water changes by 0.5°C on dissolving one mole of the ions of a solute in it, hence the boiling point of the molal aqueous solution of potassium phosphate would be ....

(a) 100.5°C (b) 99.5°C

(c) 98°C (d) 102°C

11 In the opposite diagram, if T_1 is the boiling point of solution (A), and T_2 is that of (B), both solutions (A) and (B) have the same concentration. Which of the following statements is correct ?



(a) Number of moles of ions dissolved in solution (B) is higher than that of the ions in solution (A).

(b) Number of moles of molecules which are dissolved in both solutions are equal.

(c) Number of moles of molecules dissolved in solution (A) is higher than that of the molecules in solution (B).

(d) Number of moles of ions which are dissolved in each solution is the same.

12 **Which of the following solutions of table sugar in water has the lowest boiling point ?**

(a) 2 mol/kg

(b) 1 mol/kg

(c) 0.5 mol/kg

(d) 0.1 mol/kg

13 **Which of the following aqueous solutions of the substance (X) which is nonvolatile has the highest boiling point ?**

(a) A solution contains 1 mol of (X) in 2 kg of water.

(b) A solution contains 2 mol of (X) in 1 kg of water.

(c) A solution contains 1.5 mol of (X) in 1.5 kg of water.

(d) A solution contains 0.5 mol of (X) in 1 kg of water.

14 **When the two substances (A) and (B) are added to water, each individually, two solutions are formed which have the same boiling point.**

Which of the following represents these two solutions ?

Choices	Solution (A)	Solution (B)
(a)	0.1 m sodium carbonate	0.2 m calcium nitrate
(b)	0.1 m sodium carbonate	0.1 m calcium nitrate
(c)	0.1 m potassium nitrate	0.1 m calcium nitrate
(d)	0.1 m potassium nitrate	0.2 m calcium nitrate

15 **Which of the following pairs of solutions - both have the same molal concentration - the difference between their boiling points is the highest ?**

Choices	Solution (X)	Solution (Y)
(a)	Glucose	Sodium chloride
(b)	Sodium chloride	Aluminum nitrate
(c)	Potassium carbonate	Potassium nitrate
(d)	Aluminum nitrate	Glucose

Depression of freezing point of the solution

16 **A solution is prepared by dissolving 1.25 mol of an unknown substance in 1000 g of pure water. Which of the following by measuring it we can conclude that the solute is an electrolyte or a nonelectrolyte ?**

(a) Temperature of water.

(b) Freezing point of solution.

(c) Volume of solution.

(d) Molar concentration of solution.

17 **Which of the following equally concentrated solutions has the lowest freezing point ?**

(a) $NaCl_{(aq)}$

(b) $C_6H_{12}O_{6(aq)}$

(c) $FeCl_{3(aq)}$

(d) $BaCl_{2(aq)}$

18 **Which of the following equally concentrated solutions freezes first ?**

(a) Glucose solution.

(b) Sodium carbonate solution.

(c) Sodium chloride solution.

(d) Potassium phosphate solution.

19 **Which of the following aqueous solutions whose molal concentrations are equal is preferred to be used in preventing the formation of the snow on the sidewalks in cold countries ?**

(a) $C_6H_{12}O_6$ (b) $NaBr$

(c) KNO_3 (d) $CaCl_2$

20 **Which of the following solutions its freezing point approaches that of the aqueous solution of $C_{12}H_{22}O_{11}$ whose concentration = 0.3 m ?**

(a) 0.075 m $AlCl_3$

(b) 0.15 m $CuCl_2$

(c) 0.3 m NaCl

(d) 0.6 m $C_6H_{12}O_6$

21 The freezing point of ammonium sulphate solution which contains 396 g of the salt in 1000 g of water equals .... [N = 14 , H = 1 , S = 32 , O = 16]

(a) –1.86°C
(b) 2.72°C
(c) –16.74°C
(d) –27.9°C

22 If the freezing point of a molal solution of a salt is –9.3°C
What is the probable chemical formula of this salt ?

(a) Na_3PO_4
(b) $Al_2(SO_4)_3$
(c) NH_4Br
(d) $MgCl_2$

23 The colligative properties of solutions depend on the ....

(a) nature of the solvent.
(b) nature of the solute.
(c) number of particles of the solvent.
(d) number of particles of the solute.

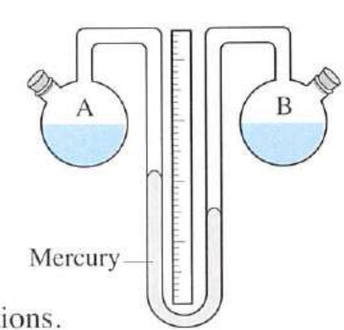
24 A little amount of sodium chloride salt is added to pure water.
What is the effect of that on the boiling and the freezing points of water ?

(a) Both the boiling and freezing points are elevated.
(b) Freezing point is elevated and boiling point is dropped.
(c) Both the boiling and freezing points are dropped.
(d) Freezing point is dropped and the boiling point is elevated.

Essay questions

Colligative properties of solutions

25 The opposite figure illustrates two flasks connected with U-shaped tube which contains an amount of mercury at room temperature and under normal pressure, one of the two flasks contains pure water and the other contains salty water, both of them have the same volume :



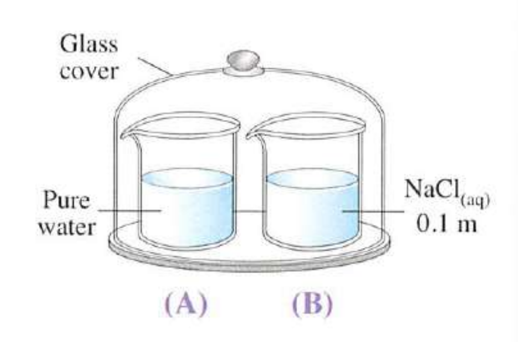
(1) Write two factors that affect the vapour pressure of the solutions.

(2) Which of the two flasks (A) or (B) contains pure water ? Explain.

(3) Suggest a method to make the two levels of mercury equal in its U-tube. "without removing the plugs of the two flasks".

26 The opposite figure represents two beakers (A) and (B) which contain x mL of each of pure water and 0.1 m NaCl salt solution respectively. **What is the change** in the volumes of the two solutions which are present in the two beakers after reaching a state of a dynamic equilibrium between water vapour and the liquids in the two beakers ? **Explain.**

«Assuming that both the temperature and the external pressure are constant».

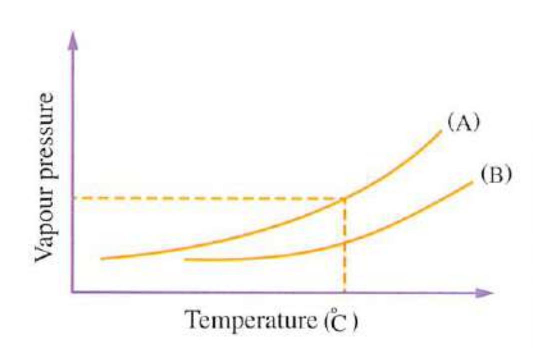


27 Two solutions, the volume of each of them is 1 L, the first solution contains 10 g of glucose $C_6H_{12}O_6$, while the second contains 10 g of sucrose $C_{12}H_{22}O_{11}$

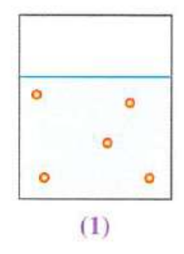
Do these solutions have the same vapour pressure ? Explain. [C = 12 , H = 1 , O = 16]

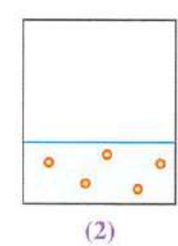
28 The opposite graphical figure represents the relation between the two vapour pressures of two pure liquids (A) and (B) at different temperatures.

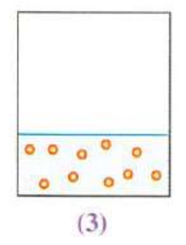
Which of the two liquids has higher boiling point ? **Explain.**

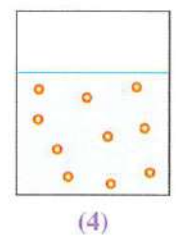


29 **The following figures represent four aqueous solutions which contain the same nonvolatile solute in closed vessels at the same temperature :**


(1)


(2)


(3)


(4)

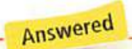
(1) Determine the number of the solution which has :

1– The highest vapour pressure. **2–** The lowest vapour pressure.

3– The lowest freezing point. **4–** The highest boiling point.

(2) Determine the numbers of the two solutions which have the same vapour pressure.

New types of questions ?



Choosing two out of five choices questions :

1 **Which of the following equally concentrated solutions (1 M) has a boiling point equal to that of 1 M aqueous solution of aluminum nitrate ?**

(a) Sodium phosphate.

(b) Potassium iodide.

(c) Calcium carbonate.

(d) Ammonium nitrate.

(e) Aluminum chloride.

2 **The opposite table shows the chemical formulas of 4 aqueous solutions which have the same volume and concentration.**
Which of the following is correct ?

Solution	Chemical formula
W	$NaCl$
X	$C_6H_{12}O_6$
Y	$CaCl_2$
Z	K_3PO_4

(a) Solution (Z) has the highest boiling point and the least vapour pressure.

(b) Solution (W) has the least vapour pressure and the least boiling point.

(c) Solution (Y) has the highest vapour pressure and the highest freezing point.

(d) Solution (X) has the highest freezing point and the highest vapour pressure.

(e) Solution (Z) has the highest boiling point and the highest vapour pressure.

Mixtures properties

* **Previously, the mixtures were already classified into :**

1 **Solutions.** 2 **Suspensions.** 3 **Colloids.**

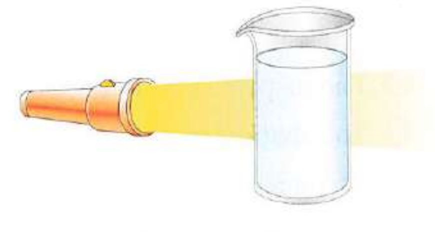
* **Following, the physical properties of each will be discussed.**

1 Solutions

* **Solution** is a homogeneous mixture in which the diameter of its particles is smaller than 1 nm

Properties of solution :

1. Homogeneous mixture.
2. The diameter of its particles (ions or molecules) is less than 1 nm
3. The particles of solution can't be distinguished by the naked eye or by the electronic microscope.
4. The particles forming the solution are regularly distributed. Consequently, the solution is homogeneous in its composition and properties.
5. The particles don't scatter the beam of light but allow the light to pass through it.

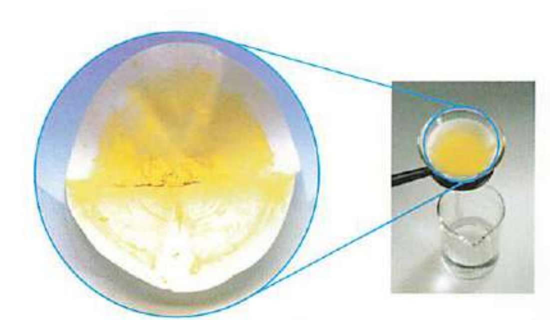


The solution doesn't scatter the light falling on it

2 Suspensions

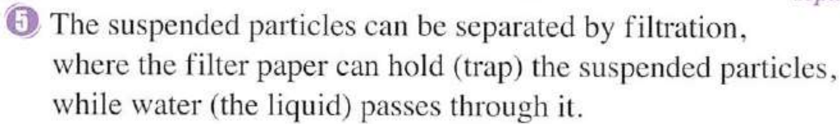
* **Suspension** is a heterogeneous mixture in which the diameter of its particles is larger than 1000 nm and can be distinguished by the naked eye.

Properties of suspension :



Suspended particles can be separated by filtration

1. Heterogeneous mixture.
2. The diameter of its particles is larger than 1000 nm
3. The suspended particles can be distinguished by the naked eye.
4. The suspended particles precipitate, if left for a short time without shaking.



5. The suspended particles can be separated by filtration, where the filter paper can hold (trap) the suspended particles, while water (the liquid) passes through it.

Examples

- **Mixture of sand in water.**
- **Mixture of chalk powder in water.**

3 Colloids

* Colloid *is a heterogeneous mixture in which the diameter of its dispersed particles ranges between 1 : 1000 nm and can be distinguished by the electronic microscope.*

Properties of colloid :

Aerosols are colloids take cloud shape

1. Heterogeneous mixture (apparently homogeneous).
2. The diameter of the dispersed particles ranges between (1 : 1000 nm).
3. The dispersed particles can be distinguished under the electronic microscope only.
4. The dispersed particles don't precipitate, if left without shaking.
5. The dispersed particles can't be separated by filtration.
6. The shape depends on its concentration :
   - **Concentrated colloids** appear as milk or clouds.
   - **Very dilute colloids** appear clear.

Tendal's phenomenon

The true solution allows the light falling on it to pass through, due to the small diameter of its particles, while the dilute colloid scatters the light because the size of the colloid particles is relatively larger, this is known as Tendal's phenomenon.

Solution allows a beam of light to pass through it, but dilute colloid scatters it " Tendal's phenomenon "

Note

The colloid is an intermediate case between the solution and the suspension, because the diameters of colloid particles are in the range between (1 : 1000 nm), which is smaller than that of suspension (>1000 nm) and larger than that of solution (<1 nm).

Colloidal systems

Colloidal systems consist of :

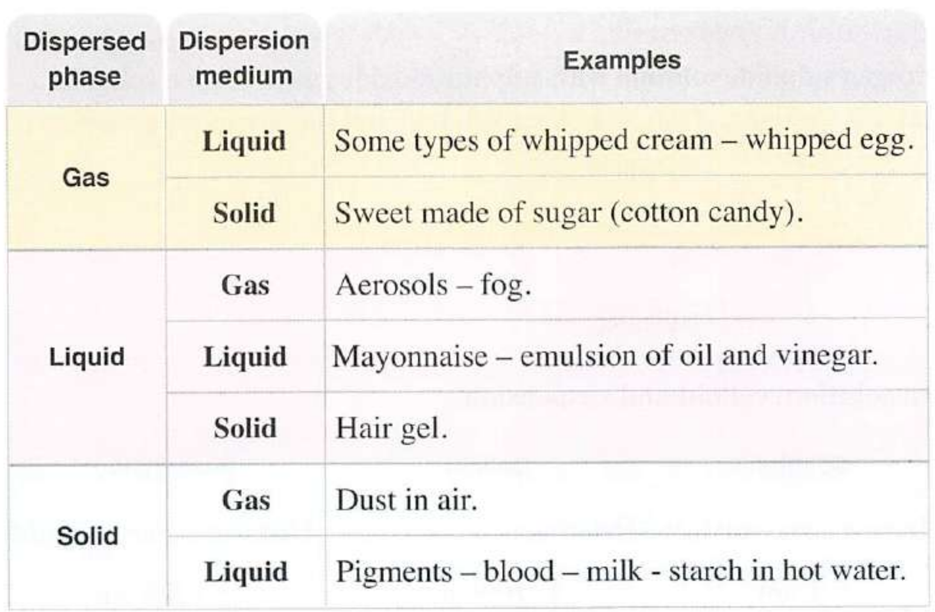
- **Dispersed phase** (like **the solute** in the solution).
  It is the substance that forms the colloidal particles.
- **Dispersion medium** (like **the solvent** in the solution).
  It is the medium in which the colloidal particles are dispersed.

For illustration

☆ **How to make natural hair gel :**

- Placing flaxseeds in a cup of water and boiling them for 5 min
- Filtering the mixture through a piece of gauze, an odour and a colour can be added.

* **Classification of colloidal systems according to the state :**



Dispersed phase	Dispersion medium	Examples
Gas	Liquid	Some types of whipped cream – whipped egg.
	Solid	Sweet made of sugar (cotton candy).
Liquid	Gas	Aerosols – fog.
	Liquid	Mayonnaise – emulsion of oil and vinegar.
	Solid	Hair gel.
Solid	Gas	Dust in air.
	Liquid	Pigments – blood – milk - starch in hot water.

Cotton candy is a colloidal system gas (air) in solid (sugar)

Pigments are colloidal systems solid (painting powder) in liquid (dispersion medium)

Application

- **When an amount of egg white is whipped by an electric hand mixer,** a colloidal system (gas in liquid type) is formed.
- **There is no gas in gas colloidal system,** because mixed gases are homogeneous mixtures, whereas the colloid is a heterogeneous mixture.

Methods of preparing the colloids

There are two methods :

Dispersion method

- The substance is crushed into small particles until its diameter ranges between (1 : 1000 nm), then added to the dispersed medium with stirring.

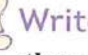
Condensation method

- The small particles are collected together into larger particles have the volume of the colloid particles, by some processes like :
  - **Hydrolysis.**
  - **Oxidation-reduction.**

Example

- When starch is stirred in water with heating, a colloid is formed by dispersion method, as the large sized starch particles are **fragmented** into smaller particles which disperse in water (dispersion medium).

- The reaction of hydrogen sulphide solution with sulphur dioxide gas, where the atoms of sulphur in water form a colloid as the atoms of sulphur **aggregate** together to form colloidal particles.



Write the equation which represents

the reaction of hydrogen sulphide solution with sulphur dioxide gas to form a colloidal system of sulphur atoms in water, illustrating the oxidation and the reduction processes.

Reduction

$$2H_2S_{(aq)} + SO_{2(g)} \longrightarrow 3S_{(s)} + 2H_2O_{(l)}$$

Oxidation

*** Comparison between solution, colloid and suspension :**

Points of comparison	Solution	Colloid	Suspension
Homogeneity	Homogeneous mixture	Heterogeneous mixture	Heterogeneous mixture
Size of particles (diameter)	< 1 nm	1 : 1000 nm	> 1000 nm
Distinguishing the particles	Can't be seen by the naked eye or distinguished by the microscope	Can't be seen by the naked eye, but distinguished by the microscope only	Can be seen by the naked eye
Scattering light beam	Doesn't scatter the light but allows it to pass	Scatters the light	Scatters the light
Precipitation	Do not precipitate	Do not precipitate	Precipitate
Filtration (separation) of particles	Can't be separated	Can't be separated	Can be separated

Worked Example

One of the students carried out the following experiments to find out the type of the mixture formed by shaking mercury in petroleum oil.

	Experiment	Observation
(1)	On falling a beam of light on the mixture	The light is scattered
(2)	On leaving the mixture for some minutes after shaking	Mercury precipitates in oil
(3)	On pouring the mixture in a funnel contains a filter paper	Mercury is separated from oil

Depending on these observations.

What is the type of this mixture ?

(a) Solution.

(b) Colloid.

(c) Suspension.

(d) Blend.

Idea of answering :

∵ The solution allows the light falling on it to pass through, while this mixture scatters it.

∴ The mixture is not a solution.

∴ The choice (a) is excluded.

∵ The colloid particles do not precipitate after shaking, and its components can not be separated by filtration.

∴ The mixture is not a colloid.

∴ The choice (b) is excluded.

∵ The suspension scatters the light falling on it, its particles precipitate after shaking and its components can be separated by filtration.

∴ This mixture is a suspension.

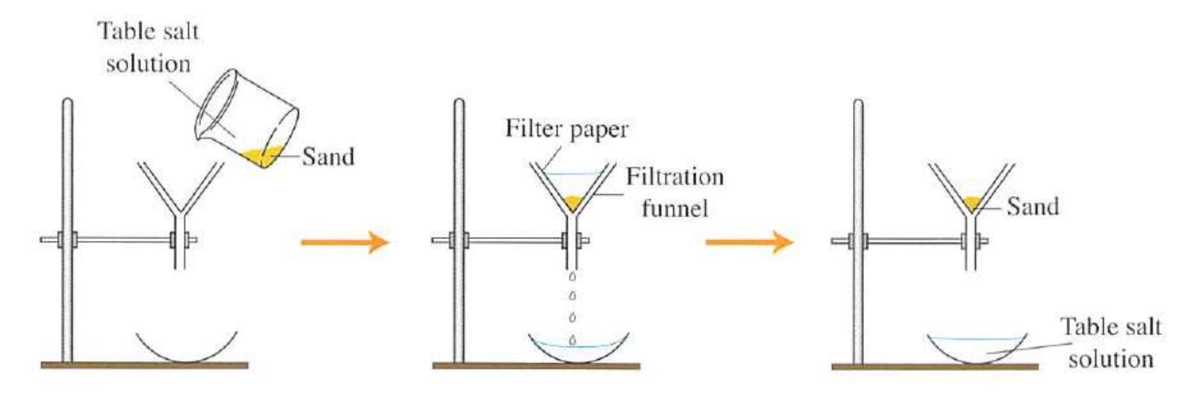
Answer : The correct choice is (c)

Methods of separating the mixtures

* **Among the methods of separating the mixtures are :**

1 Filtration

* **Separating the components of a mixture of solid substances, some of them are soluble, and some are insoluble by using a filtration funnel and a filter paper.**
* **Example :** Separating of sand from table salt in their mixture using water as a solvent.



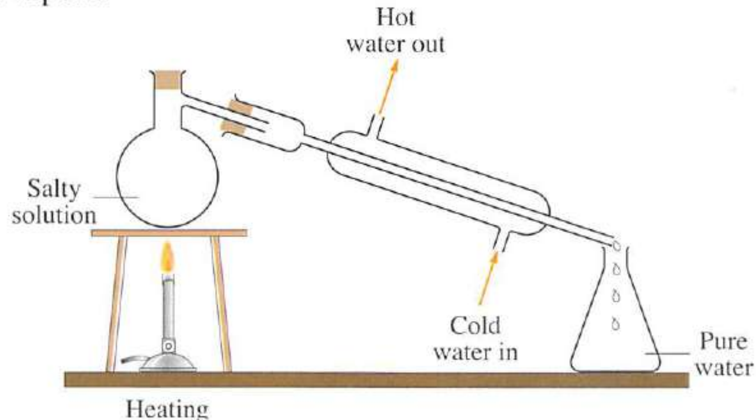
2 Evaporation

* **Separating a solid substance dissolved in a solution by heating.**
* **Example :** Separating of table salt from its solution by heating till complete evaporation of water.

Salty solution

3 Simple distillation

* **Separating the solvent from a solution by heating and condensation.**
* **Example :** Separating pure water from a salty solution by evaporation, then condensation of the produced vapour.

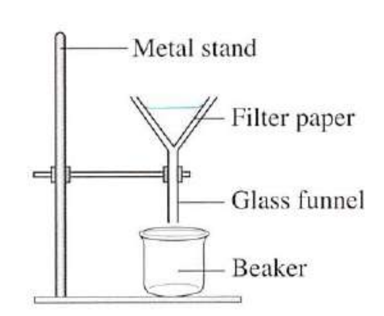


Worked Example

A filtration process was carried out for a liquid mixture using the apparatus shown in the opposite figure, after the end of the process, it was found that the mass of the dried filter paper did not change.

What do you expect the type of this mixture could be ?

It could be either ....



(a) a solution or a colloid only.

(b) a suspension or a solution only.

(c) a colloid or a suspension only.

(d) a solution, a suspension or a colloid.

Idea of answering :

∵ The mass of the dried filter paper did not change.

∴ The filter paper did not trap the solid particles of the mixture.

∵ The particles of each of the solution and the colloid pass through the filter paper.

∴ This mixture could be either a solution or a colloid.

Answer : The correct choice is (a)

Preliminary questions to remember the main concepts of the lesson

Answer them yourself

1 Choose the correct answer :

(1) The particles that form the solution ....

a. are invisible.
b. are visible.
c. can be separated by filtration.
d. scatter the light.

(2) In the colloid, what corresponds the solvent in the solution is the ....

a. dispersed phase.
b. solute.
c. dispersion medium.
d. suspension.

(3) Cotton candy and chalk powder in water are ....

a. colloids.
b. suspensions.
c. heterogeneous mixtures.
d. solutions.

(4) Dispersion medium in the emulsion of oil and vinegar is in the ....

a. solid state.
b. liquid state.
c. gaseous state.
d. vapour state.

(5) The type of the blood as a colloid is ....

a. gas in gas.
b. solid in liquid.
c. gas in solid.
d. liquid in gas.

(6) Colloids can be prepared by ....

a. polymerization.
b. dispersion.
c. precipitation.
d. hydrogenation.

2 Give reasons for :

(1) We can distinguish between the suspension and colloid by the naked eye.

(2) A mixture of sugar in water is a solution, while a mixture of milk powder in water is a colloid.

(3) The colloid can scatter the light beam falling on it.

(4) The colloid is an intermediate case between the solution and the suspension.

(5) There is no colloid of gas in gas type.

Open book questions

Answered

Multiple choice questions

Mixtures properties

1 Addition of sodium hydroxide solution to hydrochloric acid yields ....

(a) a mixture whose particles can be distinguished by the microscope.

(b) a suspension which is apparently homogeneous.

(c) a solution whose particle diameter is less than 1 nm

(d) a homogeneous mixture whose particles can be separated by filtration.

2 Table salt powder is ....

(a) a compound. (b) a solution.

(c) a colloid. (d) a suspension.

3 A mixture of sugar in kerosene is formed of particles whose diameter may equal ....

(a) 10000 nm (b) 980 nm

(c) 100 nm (d) 0.1 nm

4 Which of the following is not a suspension ?

(a) Antibiotics which need shaking before use.

(b) Muddy rains.

(c) Coffee.

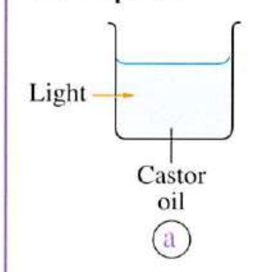
(d) Soft drinks.

5 When a light beam falls on a glass beaker contains a mixture of water and silt, it is scattered, this indicates that this mixture is ....

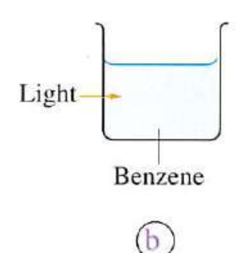
(a) a colloidal system. (b) homogeneous.

(c) a suspension. (d) a solution.

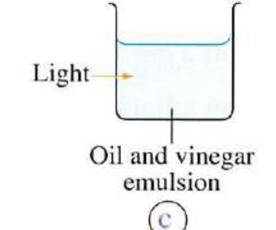
6 In which of the following beakers, the light is scattered when it passes through the liquid ?



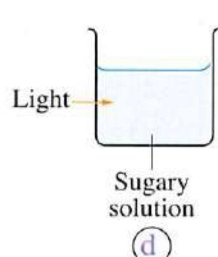
(a)



(b)



(c)



(d)

7 **The opposite figure shows a jar of mayonnaise (which is composed of eggs dispersed in oil in addition to other components). What is the type of mayonnaise mixture ?**

(a) Homogeneous solution.

(b) Apparently homogeneous suspension.

(c) Apparently homogeneous colloid.

(d) Heterogeneous suspension.

8 **Foam which is known commonly as industrial sponge, is a kind of a colloidal system similar to the type of ....**

(a) hair gel.

(b) blood.

(c) whipped egg whites.

(d) cotton candy.

9 **Jelly is similar to hair gel in that they both are ....**

(a) homogeneous mixtures.

(b) solutions.

(c) liquid in solid mixtures.

(d) suspensions.

10 **Which of the following is not a colloid ?**

(a) Milk powder in water.

(b) Dust in air.

(c) Calcium nitrate powder in water.

(d) Paints.

11 **Soap bubbles are systems in which ....**

(a) a gas is dispersed in a gas.

(b) a gas is dispersed in a liquid.

(c) a liquid is dispersed in a gas.

(d) a gas is dispersed in a solid.

12 **Cheese, hair gel and gelatin are mixtures in which ....**

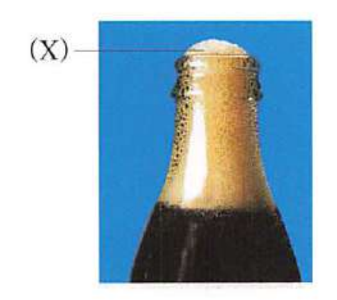
(a) a liquid dissolves in a solid.

(b) a liquid is dispersed in a solid.

(c) a solid dissolves in a liquid.

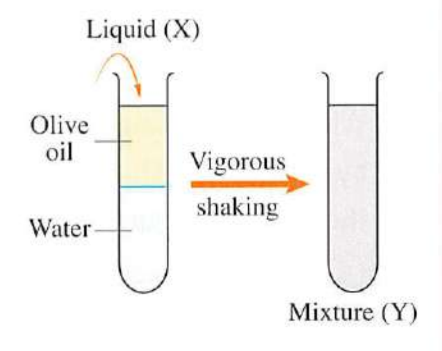
(d) a solid is dispersed in a liquid.

13 **On shaking a bottle of a soft drink, an effervescence takes place, and the colloid (X) is formed on removing the bottle cap. What is the type of the dispersed phase and of the dispersion medium in the colloid (X) ?**



Choices	Dispersed phase	Dispersion medium
(a)	Gas	Liquid
(b)	Liquid	Solid
(c)	Liquid	Gas
(d)	Solid	Gas

14 **On adding liquid (X) to a mixture of olive oil and water, mixture (Y) is formed, as in the figure. What is the type of mixture (Y) ?**



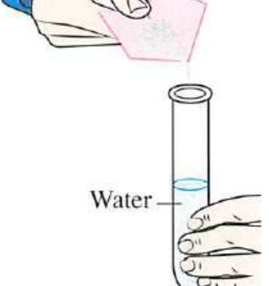
(a) Oil in water solution.

(b) Oil and water suspension.

(c) Oil in water emulsion.

(d) Oil and water amalgam.

15 **On adding a little amount of maize starch to cold water with good stirring, a mixture is formed which cannot be separated by filtration. Which of the following represents the type of this mixture ?**



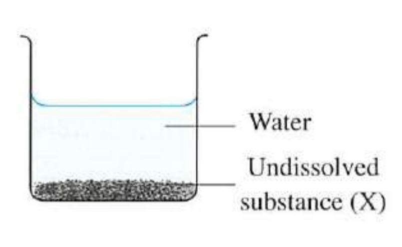
Choices	Homogeneous	Solution	Suspension	Colloid
(a)	✗	✓	✗	✓
(b)	✓	✓	✗	✗
(c)	✗	✗	✗	✓
(d)	✓	✗	✓	✗

Methods of separating the mixtures

16 **The opposite figure represents the filtration of a mixture formed from a solution, a suspension and a colloid. Which of the following shows the particles of each of them in the light of your understanding of the properties of these mixtures ?**

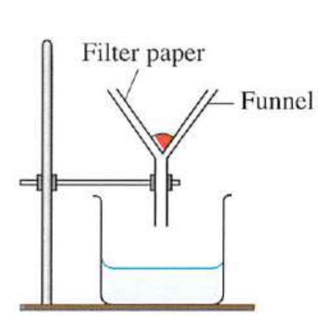
Choices	(A)	(B)	(C)
(a)	Solution particles	Suspension particles	Colloid particles
(b)	Colloid particles	Suspension particles	Solution particles
(c)	Colloid particles	Solution particles	Suspension particles
(d)	Solution particles	Colloid particles	Suspension particles

17 **What is the suitable method to separate substance (X) from water in the mixture which is illustrated in the opposite figure ?**



(a) Simple distillation.
(b) Vapourization.
(c) Filtration.
(d) Magnetic separation.

18 **What is the mixture which can be separated by the method illustrated in the opposite figure ?**



(a) Copper and aqueous solution of copper (II) chloride.
(b) An aqueous solution of copper (II) chloride and sodium chloride.
(c) Water and ethyl alcohol.
(d) Ethylene glycol and water.

19 **Which of the following separation methods proves that sodium chloride acts as a solute in sea water ?**

(a) Condensation.
(b) Fractional distillation.
(c) Vapourization.
(d) Filtration.

20 **What is the property on which the separation of sand from the table salt solution in their mixture is based ?**

(a) Concentration of the ions.
(b) Volume of the sample.
(c) Mass of the sample.
(d) Size of the particles.

21 **What are the steps followed to separate potassium nitrate salt from a mixture with calcium phosphate ?**

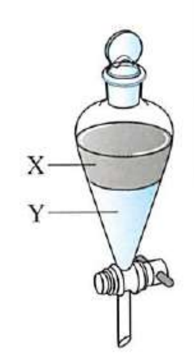
(a) Dissolving ⟶ Vaporization ⟶ Crystallization ⟶ Filtration.

(b) Dissolving ⟶ Filtration ⟶ Vaporization ⟶ Crystallization.

(c) Filtration ⟶ Crystallization ⟶ Vaporization ⟶ Dissolution.

(d) Filtration ⟶ Vaporization ⟶ Crystallization ⟶ Dissolution.

22 **The separating funnel which is illustrated in the opposite figure is used to separate the two solutions (X) and (Y).**



Which of the following represents the two liquids (X) and (Y) ?

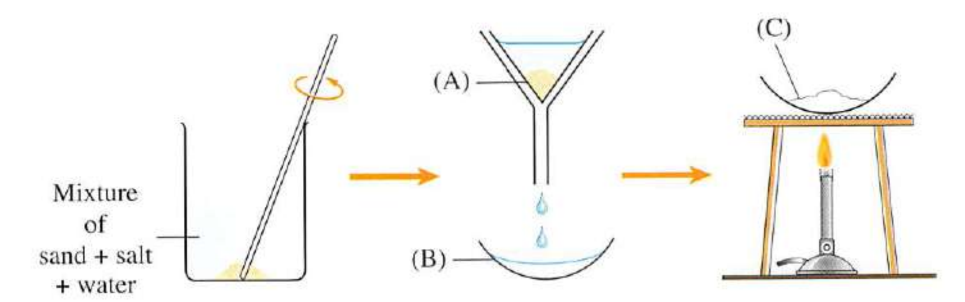
(a) Liquid (Y) acts as a dispersion medium for the liquid (X).

(b) The boiling point of liquid (Y) is higher than that of liquid (X).

(c) The two liquids (X) and (Y) form a heterogeneous mixture.

(d) The freezing point of liquid (X) is lower than that of liquid (Y).

23 **The following figures represent the followed steps in separating a mixture of sand and salt :**

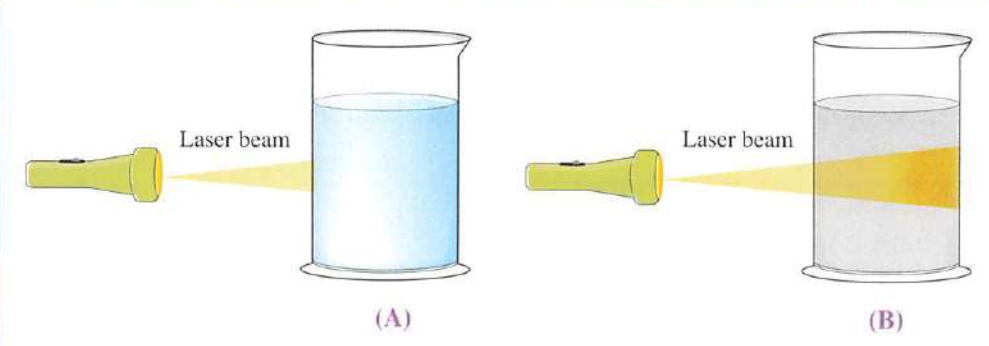


Which of the following represents (A) , (B) and (C) correctly ?

Choices	(A)	(B)	(C)
(a)	Salt	Water	Sand
(b)	Salt	Salt solution	Sand
(c)	Sand	Water	Salt
(d)	Sand	Salt solution	Salt

Mixtures properties

24 **A laser beam is passed in two different mixtures in the beakers (A) and (B) :**

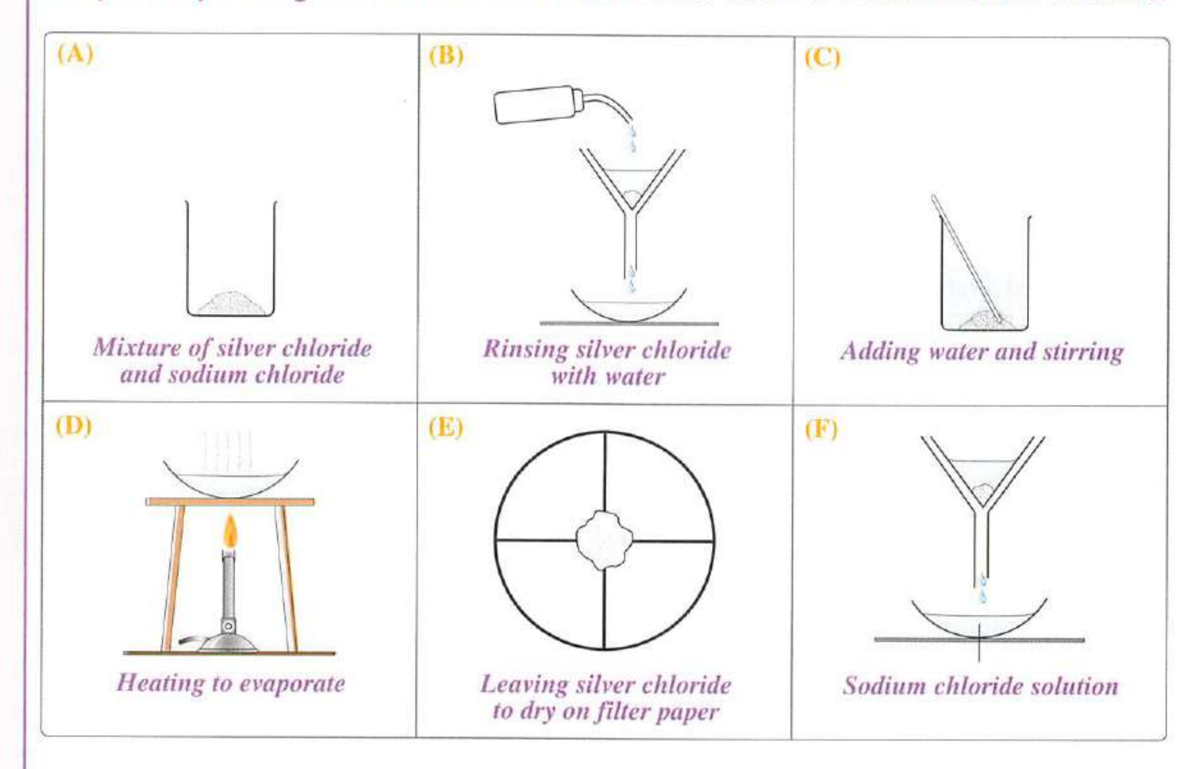


(1) Which of them is a colloid ? Explain.

(2) What is the type of the mixture which is found in the other beaker ? Explain.

Methods of separating the mixtures

25 There is a mixture of sodium chloride and silver chloride salts required to be separated, **arrange the steps which are illustrated by the following figures to state the followed steps in separating this mixture to obtain sodium chloride first then silver chloride.**



New types of questions ? Answered

Choosing two out of five choices questions :

1 **On stirring 90 g of NaCl in 100 g of water at 90°C , NaCl disappears completely. Which of the following is correct ?**

(a) A homogeneous compound of NaCl is formed.

(b) The particles of the produced mixture can be separated by filtration.

(c) On cooling, a saturated solution of NaCl is formed.

(d) The formed mixture scatters the light falling on it.

(e) The particles of the produced mixture cannot be distinguished by microscope.

2 **The opposite table shows the diameters of the particles of some mixtures. Which of the following is correct ?**

mixture	Diameters of particles (nm)
A	0.2
B	300
C	500
D	1200

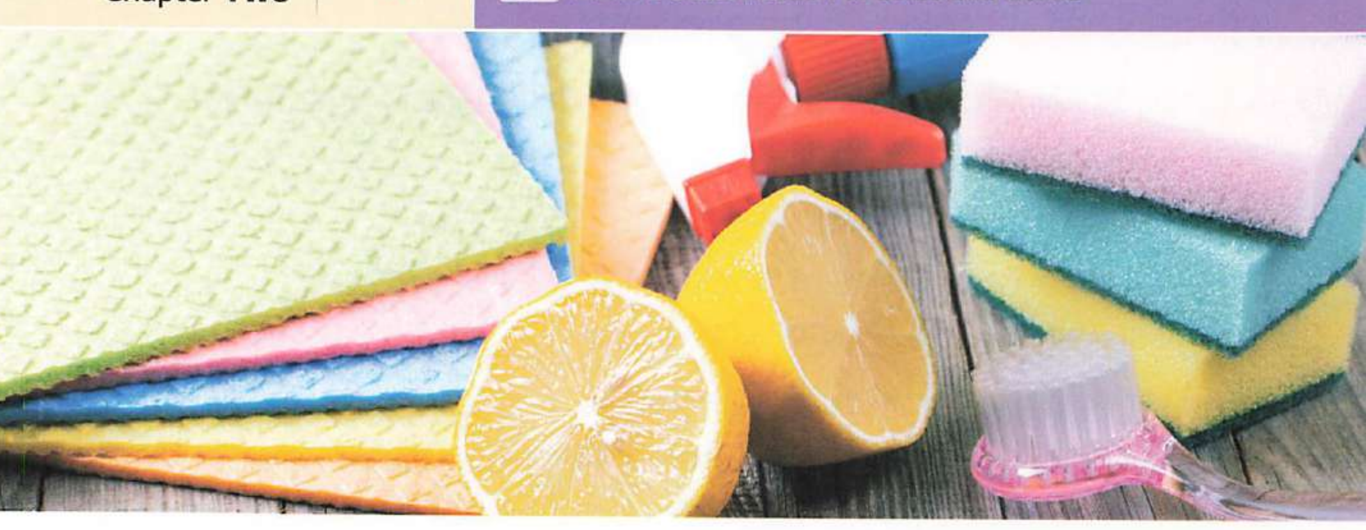
(a) Mixture (A) allows the falling light to pass through it.

(b) Mixture (B) particles can be separated by filtration.

(c) Mixture (D) particles do not precipitate after shaking.

(d) The two mixtures (A) and (D) are both heterogenous.

(e) The two mixtures (B) and (C) are both apparently homogenous.



Uses of acids and bases

* **Acids** are used in many chemical industries, like :

- Fertilizers.
- Explosives.
- Medicines.
- Plastic.
- Car batteries.

* **Bases** also have many uses in chemical industries, like :

- Soap.
- Detergents.
- Dyes.
- Medicines.

- Vinegar is a dilute solution of acetic acid, it is one of the oldest acidic solutions that was early discovered, it is used in food, as well as in cleaning processes.

Acids and bases are used in manufacture of medicines

Detergents are bases

Lemon and tomato contain acids

* **The following tables show some of the natural and industrial products and the acids and bases entering in their composition or preparation :**

Product	Acids found in its composition
Citrus plants (lemon - oranges - tomatoes)	Citric acid – Ascorbic acid
Dairy products (cheese - yogurt)	Lactic acid
Soft drinks	Carbonic acid – Phosphoric acid

Product	Bases found in its composition
Soap	Sodium hydroxide
Baking soda	Sodium bicarbonate
Washing soda	Hydrated sodium carbonate

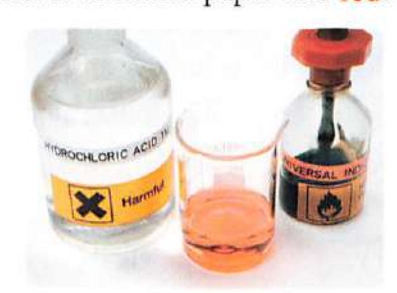
Properties of acids and bases

* **General properties of acids and bases can be compared as follows :**

Acids

(1) Have sour taste.

(2) Change the color of purple litmus indicator or litmus paper into red.



Acids change the color of litmus indicator into red

Alkalis (Bases)

(1) Have bitter taste and slippery (soapy) feel.

(2) Change the color of purple litmus indicator or litmus paper into blue.

Bases change the color of litmus indicator into blue

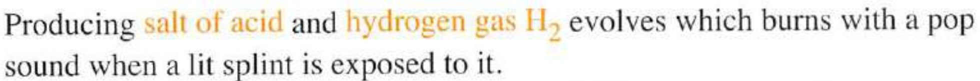
(3) **Alkalis (Bases)** react with **acids** producing **salt** and **water**

$$NaOH_{(aq)} + HNO_{3(aq)} \longrightarrow NaNO_{3(aq)} + H_2O_{(l)}$$

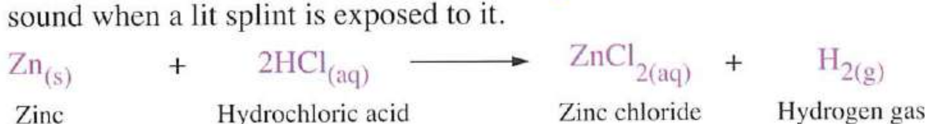
Sodium hydroxide	Nitric acid	Sodium nitrate	Water
Base	**Acid**	**Salt**	

Acids react with :

• Active metals :



Producing salt of acid and hydrogen gas H_2 evolves which burns with a pop sound when a lit splint is exposed to it.

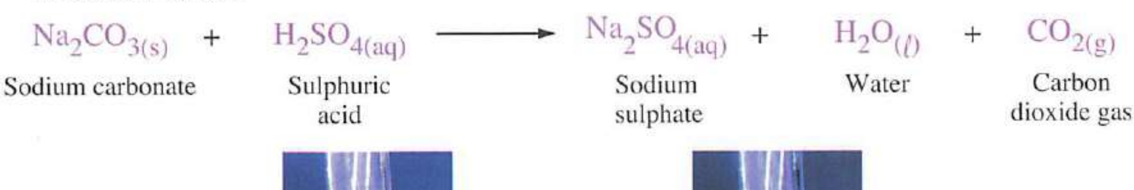


$$Zn_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$$

Zinc + Hydrochloric acid → Zinc chloride + Hydrogen gas

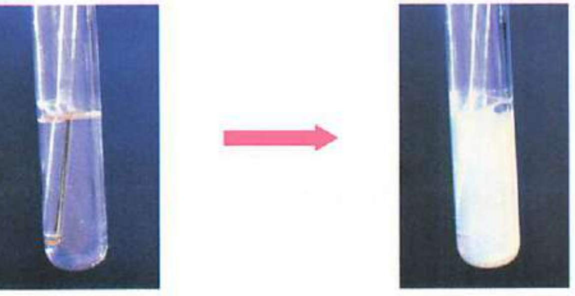
• Carbonate or bicarbonate salts :

Causing effervescence and producing carbon dioxide gas CO_2 which turns clear limewater turbid.



$$Na_2CO_{3(s)} + H_2SO_{4(aq)} \longrightarrow Na_2SO_{4(aq)} + H_2O_{(l)} + CO_{2(g)}$$

Sodium carbonate + Sulphuric acid → Sodium sulphate + Water + Carbon dioxide gas



CO_2 gas turns clear limewater turbid after passing for short time

Theories defining acids and bases

- The apparent characteristic properties of acids and bases lead to an experimental definition for each of them.
- The experimental definition is based on observation only and doesn't describe or explain the invisible properties of the acids and bases which lead to the behaviour of each of them.
- The more comprehensive definitions of acid and base come from the studies and experiments, that were placed in the form of theories.

Acid-base theories :

1. **Arrhenius theory.**
2. **Brönsted-Lowry theory.**
3. **Lewis theory.**

1 Arrhenius theory in 1884

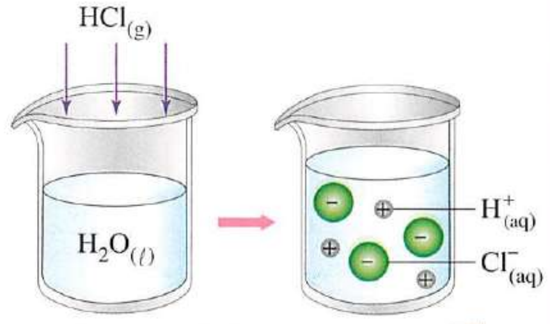
- Arrhenius observed that the aqueous solutions of acids and bases conduct electricity, so he concluded that acids and bases ionize in water forming positive and negative ions, which is shown as follows :

> **Note**
>
> **Covalent compounds** like hydrogen chloride **ionize** in water, while **ionic compounds** as sodium hydroxide **dissociate** in water

Dissolution of hydrogen chloride in water

When hydrogen chloride gas dissolves in water, it **ionizes** into hydrogen ions (H^+) and chloride ions (Cl^-)

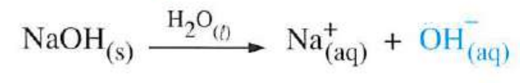
$$HCl_{(g)} \xrightarrow{H_2O_{(l)}} H^+_{(aq)} + Cl^-_{(aq)}$$



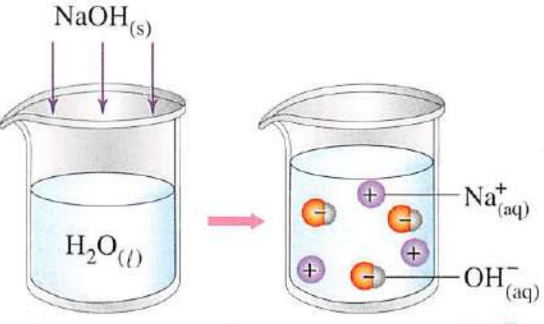
On dissolving $HCl_{(g)}$ in water it gives H^+ ions "Arrhenius acid"

Dissolution of sodium hydroxide in water

When sodium hydroxide dissolves in water, it **dissociates** to sodium ions (Na^+) and hydroxide ions (OH^-)



$$NaOH_{(s)} \xrightarrow{H_2O_{(l)}} Na^+_{(aq)} + OH^-_{(aq)}$$



On dissolving $NaOH_{(s)}$ in water it gives OH^- ions "Arrhenius base"

Based on that, Arrhenius defined acids and bases, as follows :

Arrhenius acid

Is the substance that dissolves in water and ionizes or dissociates giving one or more hydrogen ions (H^+)

Arrhenius base

Is the substance that dissolves in water and ionizes or dissociates giving one or more hydroxide ions (OH^-)

According to Arrhenius theory we observe that

Arrhenius acid must contain a source of hydrogen ions (H^+)

Arrhenius base must contain a source of hydroxide ions (OH^-)

So

Arrhenius acid acts on increasing the concentration of (H^+) ions in the aqueous solutions

$$\underset{\text{Sulphuric acid}}{H_2SO_{4(l)}} \xrightarrow{\text{water}} H^+_{(aq)} + HSO^-_{4(aq)}$$

Arrhenius base acts on increasing the concentration of (OH^-) ions in the aqueous solutions

$$\underset{\text{Potassium hydroxide}}{KOH_{(s)}} \xrightarrow{\text{water}} K^+_{(aq)} + OH^-_{(aq)}$$

Note

Positive hydrogen ion H^+ in aqueous solutions can be termed **hydronium ion H_3O^+**

Worked Example

Classify the following substances into Arrhenius acid or Arrhenius base, giving reasons :

(1) $HNO_{3(l)}$ (2) $Ba(OH)_{2(s)}$

Answer :

	Substance	Represents	Explanation
(1)	$HNO_{3(l)}$	Arrhenius acid	Because it dissolves in water giving H^+ ions. $HNO_{3(l)} \xrightarrow{H_2O_{(l)}} H^+_{(aq)} + NO^-_{3(aq)}$
(2)	$Ba(OH)_{2(s)}$	Arrhenius base	Because it dissolves in water giving OH^- ions. $Ba(OH)_{2(s)} \xrightarrow{H_2O_{(l)}} Ba^{2+}_{(aq)} + 2OH^-_{(aq)}$

Explaining neutralization reaction according to Arrhenius theory

Neutralization reaction is the reaction between an acid and a base to produce salt (an ionic compound) and water.

Application

$$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$$

Hydrochloric acid | Sodium hydroxide | Sodium chloride | Water

- The ionic equation of this reaction according to Arrhenius theory is :

$$H^+_{(aq)} + \cancel{Cl^-_{(aq)}} + \cancel{Na^+_{(aq)}} + OH^-_{(aq)} \longrightarrow \cancel{Na^+_{(aq)}} + \cancel{Cl^-_{(aq)}} + H_2O_{(l)}$$

$Na^+_{(aq)}$ and $Cl^-_{(aq)}$ ions are present in both sides of the equation without changing.

So they can be cancelled from the both sides of the chemical equation.

So the neutralization reaction can be represented by the following equation :

$$H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)}$$

Drawbacks of Arrhenius theory

* Arrhenius theory cannot define all types of acids and bases, for example it cannot explain the fact that :
  - Some compounds like carbon dioxide CO_2 do not contain a source of (H^+) ions, but they dissolve in water giving aqueous acidic solutions.
  - Some compounds like ammonia NH_3 do not contain a source of (OH^-) ions, but they dissolve in water giving aqueous basic solutions.

Test Yourself

Which of the following compounds is an Arrhenius acid ?

(a) HBr (b) NaOH (c) NaBr (d) NH_3

Answer : The correct choice is ....

2 Brönsted-Lowry theory in 1923

The Danish scientist Brönsted and the British scientist Lowry proposed a new acid-base theory, where they could explain the acidity and the basicity of the compounds which Arrhenius failed to explain.

Brönsted-Lowry acid

It is the substance that donates the proton (H^+).

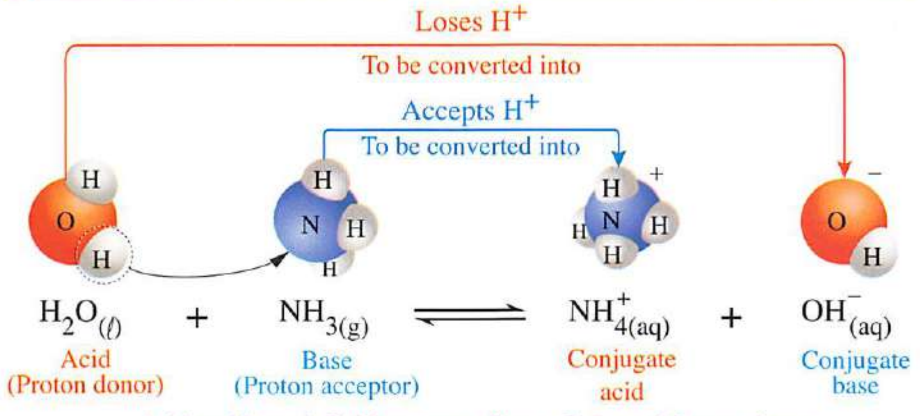
(proton donor)

Brönsted-Lowry base

It is the substance that accepts the proton (H^+).

(proton acceptor)

Brönsted-Lowry theory describes the behavior of ammonia as a base.



Acid and base definitions according to Brönsted-Lowry theory

When ammonia gas dissolves in water

H_2O acts as an acid, **because** it donates a proton (H^+) to ammonia molecule (NH_3)

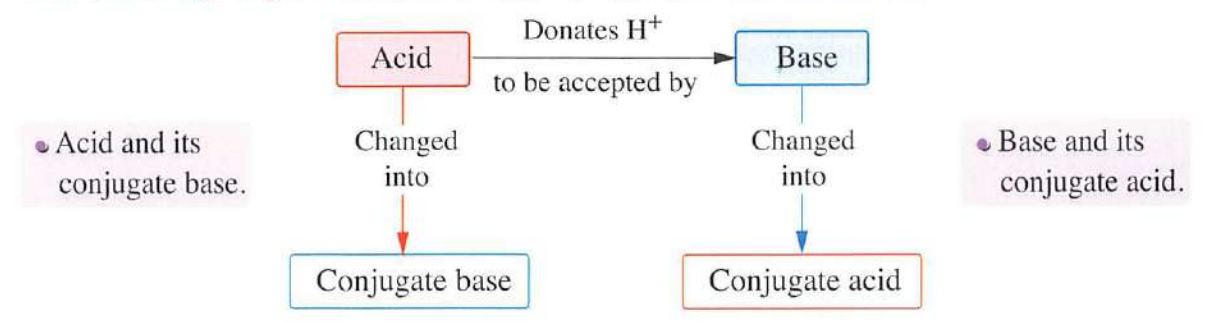
NH_3 acts as a base, **because** it accepts the proton (H^+) from water molecule

As a result of this transfer

OH^- ion is formed (remained from the acid) and it is called **conjugate base** which is the substance which is formed when the acid loses a proton (H^+)

NH_4^+ ion is formed (after the base acquired a proton) and it is called **conjugate acid** which is the substance which is formed when the base accepts a proton (H^+)

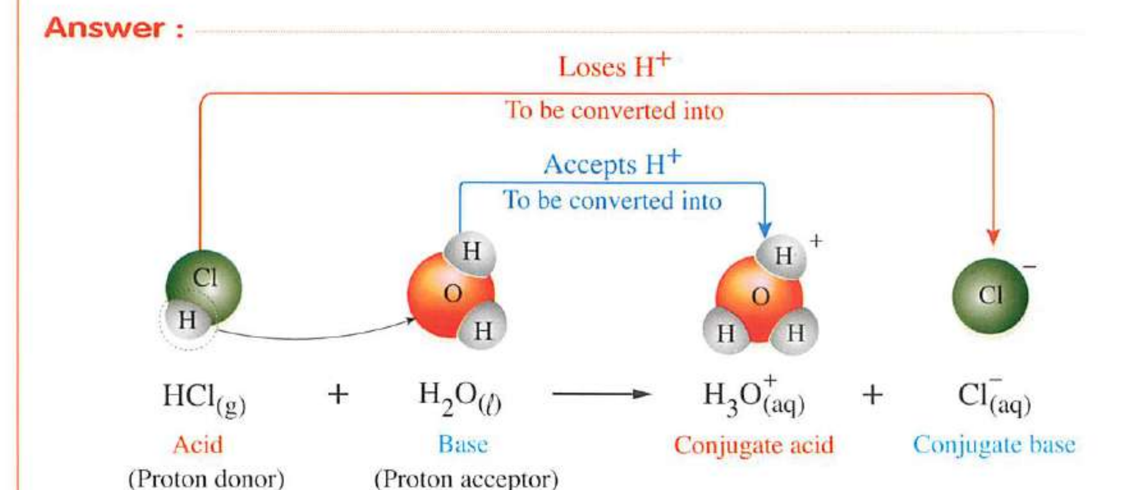
* The following diagram shows the relation between acid and base :



Worked Examples

1 Write the chemical equation which represents **the dissolution of hydrogen chloride gas $HCl_{(g)}$ in water according to Brönsted-Lowry theory,** then identify **the acid, the base and their conjugates.**

Answer :



$$HCl_{(g)} + H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$

Acid (Proton donor) | Base (Proton acceptor) | Conjugate acid | Conjugate base

∵ HCl loses a proton to be converted into Cl^-

∴ **The acid** is hydrogen chloride gas $HCl_{(g)}$

The conjugate base is chloride ion $Cl^-_{(aq)}$

∵ H_2O accepts a proton to be converted into H_3O^+

∴ **The base** is water $H_2O_{(l)}$

The conjugate acid is hydronium ion $H_3O^+_{(aq)}$

Included information

Some substances are amphoteric, **i.e.** they act as acids (proton donors) in some reactions, and as bases (proton acceptors) in other reactions.

2 **The following reaction proceeds in both directions :**

$$HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$$

What are the two acids which exist in the reaction medium according to Brönsted- Lowry theory ?

(a) H_2O and OH^-
(b) HCO_3^- and OH^-
(c) H_2O and H_2CO_3
(d) HCO_3^- and H_2CO_3

Idea of answering :

- $HCO_3^- + H_2O \longrightarrow H_2CO_3 + OH^-$

  ∵ H_2O donates a proton to HCO_3^- ion.

  ∴ H_2O acts as an acid in this reaction.

  ∴ The choices (b) and (d) are excluded.

- $H_2CO_3 + OH^- \longrightarrow HCO_3^- + H_2O$

  ∵ H_2CO_3 donates a proton to OH^- ion.

  ∴ H_2CO_3 acts as an acid.

Answer : The correct choice is (c)

Test Yourself

In the following reaction :

$$CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons CH_3COO^-_{(aq)} + H_3O^+_{(aq)}$$

What is the pair which represents the conjugate acid and the base respectively ?

(a) $CH_3COOH_{(aq)}$, $H_2O_{(l)}$
(b) $CH_3COO^-_{(aq)}$, $H_3O^+_{(aq)}$
(c) $H_2O_{(l)}$, $CH_3COO^-_{(aq)}$
(d) $H_3O^+_{(aq)}$, $H_2O_{(l)}$

Answer : The correct choice is ....

3 Lewis theory in 1923

Lewis proposed a more comprehensive acid-base theory which depends on sharing a lone pair of electrons between acid and base instead of transferring the protons.

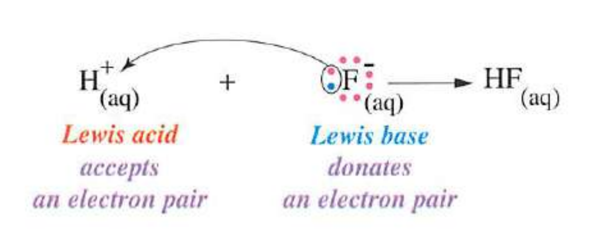
Lewis acid

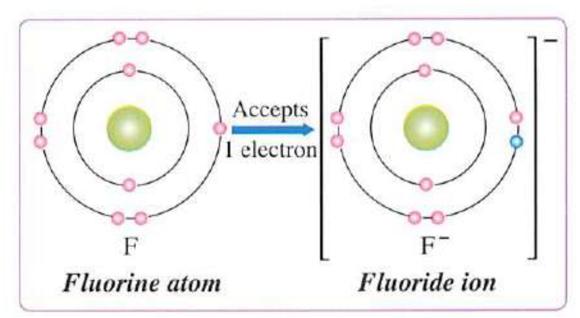
It is the substance that accepts a lone pair of electrons or more.

Lewis base

It is the substance that donates a lone pair of electrons or more.

Application Lewis theory explains the reaction of formation of hydrogen fluoride HF





According to Lewis

Hydrogen ion H^+ is the acid, as it accepts a free (lone) pair of electrons from fluoride ion F^-

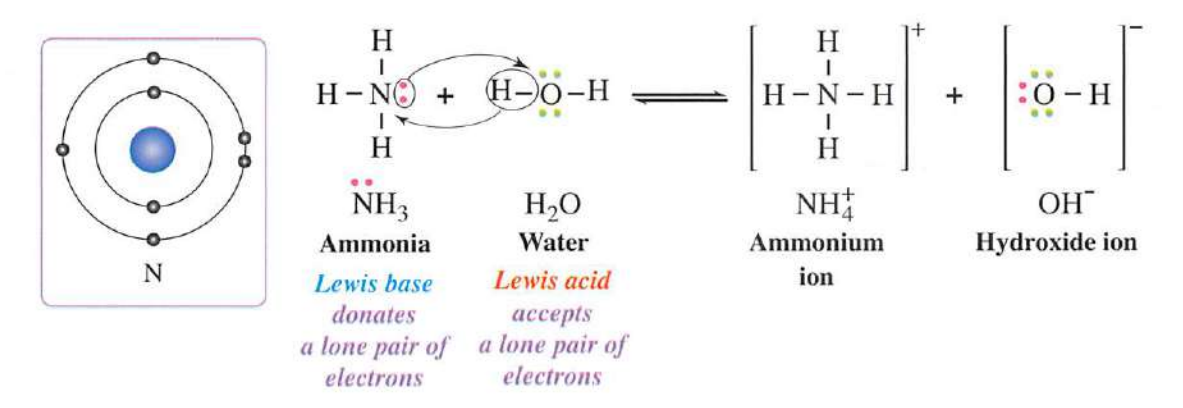
Fluoride ion F^- is the base, as it gives (donates) a free (lone) pair of electrons to hydrogen ion H^+

Worked Example

Which of the following shows both the acid and the base in the dissolving process of ammonia gas NH_3 in water H_2O according to Lewis theory ?

Choices	Acid	Base
(a)	Ammonia gas	Water
(b)	Ammonia gas	Ammonium ion
(c)	Water	Ammonia gas
(d)	Ammonium ion	Ammonia gas

Idea of answering :



∵ Ammonia gas donates its lone pair of electrons to water.

∴ Ammonia gas is the Lewis base.

∴ The choices (a) and (b) are excluded.

∵ Water accepts the lone pair of electrons from ammonia gas.

∴ Water is the Lewis acid.

Answer : The correct choice is (c)

Note

Ammonia is considered as a base, although it doesn't contain hydroxide ions (OH^-) in its composition, because according to Brönsted-Lowry theory, ammonia accepts a proton from another substance (as water) during the reaction, and according to Lewis theory it donates a lone pair of electrons to another substance (as water) during the reaction.

All the previous theories can be summarized as the following :

Theory	Acid	Base
Arrhenius	The substance that dissolves in water, giving one or more positive hydrogen ions H^+ $HCl_{(g)} \xrightarrow{water} H^+_{(aq)} + Cl^-_{(aq)}$	The substance that dissolves in water, giving one or more hydroxide ions OH^- $NaOH_{(s)} \xrightarrow{water} Na^+_{(aq)} + OH^-_{(aq)}$
Brönsted-Lowry	The substance that donates a proton H^+	The substance that accepts a proton H^+
	$HCl_{(g)} + H_2O_{(\ell)} \longrightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$ HCl: Acid, H_2O: Base, H_3O^+: Conjugate acid, Cl^-: Conjugate base	
Lewis	The substance that accepts a lone pair of electrons or more	The substance that donates a lone pair of electrons or more
	$H^+_{(aq)} + F^-_{(aq)} \longrightarrow HF_{(aq)}$ H^+: Acid, F^-: Base	

Preliminary questions to remember the main concepts of the lesson

Answer them yourself

1 Choose the correct answer :

(1) What is the acid which is found in citrus plants ?

a. Phosphoric acid. b. Lactic acid.

c. Ascorbic acid. d. Carbonic acid.

(2) From the properties of acids ....

a. having a sour taste. b. changing litmus indicator to blue.

c. having slippery feel. d. having bitter taste.

(3) Reactions of the acids with carbonate or bicarbonate salts yield ....

a. hydrogen. b. oxygen.

c. carbon dioxide. d. sulphur dioxide.

(4) In the reaction of ammonia and hydrochloric acid, ammonium ion (NH_4^+) is ....

a. a conjugate base. b. the base.

c. a conjugate acid. d. the acid.

(5) The conjugate acid of HSO_4^- is ....

a. HSO_4^+ b. SO_4^{2-}

c. H_2SO_4 d. H^+

(6) The substance which donates a lone pair of electrons or more is considered as ....

a. a Lewis acid. b. an Arrhenius acid.

c. a Lewis base. d. an Arrhenius base.

2 Give reasons for :

(1) Hydrogen chloride gas is an Arrhenius acid when it is dissolved in water.

(2) Arrhenius theory has drawbacks.

(3) Ammonia gas isn't considered to be a base according to Arrhenius theory, but considered to be in Brönsted-Lowry theory.

Open book questions

Answered

Multiple choice questions

Uses and properties of acids and bases

1 **Which of the following is a property of sodium hydroxide ?**

(a) It dissolves in water yielding H^+
(b) Its aqueous solution has a slippery feel.
(c) It turns the colour of litmus from purple to red.
(d) It reacts with magnesium and hydrogen gas evolves.

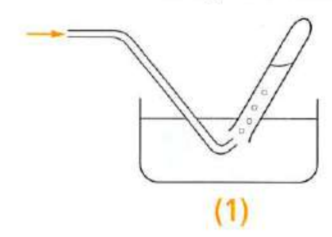
2 **The reaction of baking soda with sulphuric acid causes the evolution of bubbles of ....**

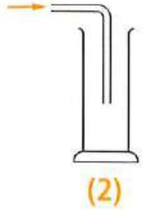
(a) sulphur dioxide gas.
(b) nitrogen dioxide gas.
(c) hydrogen gas.
(d) carbon dioxide gas.

3 **Acids react with bases to form salt and water.**
Which of the following represents the solubilities of the reactants in water ?

Choices	Acid	Base
(a)	Soluble	Insoluble
(b)	Insoluble	Soluble
(c)	Soluble	Soluble
(d)	Insoluble	Insoluble

4 **Calcium reacts with dilute hydrochloric acid forming the gas (X) which is sparingly soluble in water and lighter than air :**


(1)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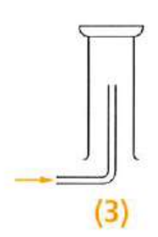

(3)

What is the name of this gas ? And what is (are) the proper method(s) to collect this gas when it is prepared in lab ?

(a) Hydrogen gas / (2) only.
(b) Chlorine gas / (1) and (3) only.
(c) Hydrogen gas / (1) and (3) only.
(d) Chlorine gas / (2) only.

Arrhenius theory

5 **Arrhenius theory for defining the acid is not applied to ....**

(a) HF in water.
(b) HCl in water.
(c) $HSO^-_{4(aq)}$
(d) I_2 in dichloroethane.

6 **Adding HCl acid to pure water results in ....**

(a) increasing the concentrations of both H^+ and OH^-
(b) increasing the concentration of H^+, and decreasing that of OH^-
(c) decreasing the concentrations of both H^+ and OH^-
(d) decreasing the concentration of H^+, and increasing that of OH^-

Brönsted-Lowry theory

7 **In the reaction : $H_2S_{(aq)} + CH_3NH_{2(aq)} \rightleftharpoons HS^-_{(aq)} + CH_3NH^+_{3(aq)}$**

Which of the following represents this reaction ?

(a) H_2S is H^+ ion donor , while CH_3NH_2 is H^+ ion acceptor.
(b) CH_3NH_2 is H^+ ion donor , while H_2S is H^+ ion acceptor.
(c) Both HS^- and $CH_3NH_3^+$ are H^+ ion donors.
(d) Both HS^- and $CH_3NH_3^+$ are H^+ ion acceptors.

8 **In the following equation :**

$$HCl_{(g)} + H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$

Which of the following statements represents what happens in this reaction ?

(a) Chloride ion is formed by gaining an electron from water.
(b) Hydrogen chloride molecule loses an electron forming chloride ion.
(c) Water gains a proton from hydrogen chloride.
(d) Water donates a proton to hydrogen chloride.

9 **The conjugate acid of the base $HAsO_4^{2-}$ is ....**

(a) H_3O^+
(b) AsO_4^{3-}
(c) H_3AsO_4
(d) $H_2AsO_4^-$

10 **What is the conjugate base of the acid $H_2BO_3^-$?**

(a) BO_3^{3-}
(b) H_3BO_3
(c) HBO_3^{2-}
(d) $H_3BO_2^+$

11 The conjugate base of ethanol C_2H_5OH is ....

(a) CH_3CH_2OH

(b) $C_2H_5OH_2$

(c) $CH_3CH_2O^-$

(d) CH_3OCH_3

12 All the following are Brönsted - Lowry acids, except ....

(a) CH_3COO^-

(b) HCO_3^-

(c) HSO_3^-

(d) NH_4^+

13 Which of the following pairs does not represent a conjugate acid and its base respectively ?

(a) NH_4^+ , NH_3

(b) H_2S , HS^-

(c) H_3O^+ , H_2O

(d) NH_2^- , NH_3

14 Which of the following ions can not behave as a base and as an acid in different reactions ?

(a) $H_2PO_4^-$

(b) CO_3^{2-}

(c) HCO_3^-

(d) HSO_4^-

15 Water acts as a Brönsted - Lowry acid when it reacts with ....

(a) NH_3

(b) H_2S

(c) HCN

(d) HNO_3

16 In the reaction : $CH_3COOH_{(aq)} + NH_{3(g)} \rightleftharpoons CH_3COO^-_{(aq)} + NH^+_{4(aq)}$

Which of the following represents the type of each of the reactants and the products respectively ?

Choices	$CH_3COOH_{(aq)}$	$NH_{3(g)}$	$CH_3COO^-_{(aq)}$	$NH^+_{4(aq)}$
(a)	Acid	Base	Conjugate base	Conjugate acid
(b)	Conjugate acid	Conjugate base	Acid	Base
(c)	Base	Acid	Conjugate base	Conjugate acid
(d)	Conjugate base	Conjugate acid	Acid	Base

17 In the reaction : $HCO^-_{3(aq)} + H_2O_{(l)} \rightleftharpoons OH^-_{(aq)} + H_2CO_{3(aq)}$

Which of the following represents the reactants and the products according to Brönsted-Lowry theory ?

Choices	Acid	Base	Conjugate acid	Conjugate base
(a)	$HCO^-_{3(aq)}$	$H_2O_{(l)}$	$H_2CO_{3(aq)}$	$OH^-_{(aq)}$
(b)	$H_2CO_{3(aq)}$	$OH^-_{(aq)}$	$HCO^-_{3(aq)}$	$H_2O_{(l)}$
(c)	$H_2O_{(l)}$	$HCO^-_{3(aq)}$	$H_2CO_{3(aq)}$	$OH^-_{(aq)}$
(d)	$H_2O_{(l)}$	$HCO^-_{3(aq)}$	$OH^-_{(aq)}$	$H_2CO_{3(aq)}$

18 According to Brönsted - Lowry theory, the mixture of water with nitric acid has to contain ....

(a) OH^-

(b) NO_3

(c) NO_3^-

(d) NO_2^-

19 Sulphuric acid H_2SO_4 ionizes in water in two steps, represented by the two following equations :

- $H_2SO_{4(aq)} + H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + HSO^-_{4(aq)}$
- $HSO^-_{4(aq)} + H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + SO^{2-}_{4(aq)}$

What is the conjugate base of $HSO^-_{4(aq)}$ ion ?

(a) $H_2O_{(l)}$ (b) $H_3O^+_{(aq)}$

(c) $H_2SO_{4(aq)}$ (d) $SO^{2-}_{4(aq)}$

20 Bisulphate anion HSO_4^- reacts in water as an acid and as a base.

What is the reaction in which bisulphate anion acts as an acid ?

(a) $HSO_4^- + H_2O \longrightarrow H_2SO_4 + OH^-$

(b) $HSO_4^- + H_3O^+ \longrightarrow SO_3 + 2H_2O$

(c) $HSO_4^- + OH^- \longrightarrow H_2SO_4 + O^{2-}$

(d) $HSO_4^- + H_2O \longrightarrow SO_4^{2-} + H_3O^+$

21 **The basicity of hydride anion H^- is stronger than the basicity of hydroxide anion OH^-, therefore, the reaction of H^- anion with water forms ....**

(a) $H_3O^+_{(aq)}$ (b) $OH^-_{(aq)} + H_{2(g)}$

(c) $OH^-_{(aq)} + 2H^+_{(aq)}$ (d) $H_2O_{2(aq)}$

Lewis theory

22 **Lewis base ....**

(a) must be a neutral molecule.

(b) must be a charged ion.

(c) may be a neutral molecule or a charged ion.

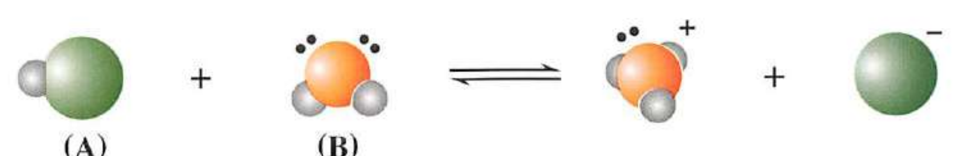
(d) must be a neutral atom.

23 **All the Brönsted - Lowry bases are ....**

(a) Lewis bases. (b) Arrhenius acids.

(c) Lewis acids. (d) Arrhenius bases.

24 **The following figure represents the two concepts of the acid and the base :**



What is (are) the theory(ies) which explain(s) the two concepts of the acid and the base in this figure ?

(a) Arrhenius theory only.

(b) Brönsted-Lowry theory only.

(c) Arrhenius and Lewis theories.

(d) Brönsted-Lowry and Lewis theories.

Essay questions and problems

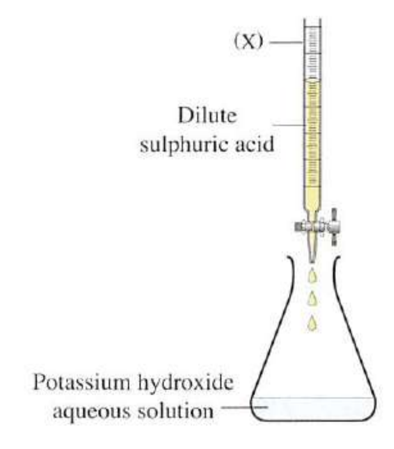
Uses and properties of acids and bases

25 Palmitic acid is found in almost all natural fats, known commercially as palm acid, while sodium bicarbonate is known commercially as baking soda.

How can you differentiate between palm acid and baking soda ?

26 **Write the balanced symbolic equation which represents** the reaction of an acid with a base to form a salt formed of Mg^{2+} cations and Cl^- anions.

27 **Study the opposite figure, then answer the following :**



(1) What is the name of the tool (X) ?

Where is the zero mark located in its scale ?

(2) Write the symbolic equation which represents the occurring reaction.

(3) Write the net ionic equation in the light of Arrhenius theory.

Theories defining acids and bases

28 Basic properties of the basic substances do not appear except when they are present with acidic substances.

What is (are) the theory(ies) which explain(s) the previous statement ?

29 "The existence of H^+ ions in an aqueous solution causes a litmus paper to be red".

What is the source of H^+ ions in the aqueous solutions.

Is it an Arrhenius acid, a Brönsted – Lowry acid or a Lewis acid ?

30 **Complete the following equation which illustrates** the dissolution of hydrazine in water, knowing that it acts as a Brönsted – Lowry base :

$$N_2H_{4(aq)} + H_2O_{(\ell)} \rightleftharpoons \text{..............} + \text{..............}$$

31 In the equilibrium process : $SbF_5 + 2HF \rightleftharpoons SbF_6^- + H_2F^+$

Illustrate the behaviour of HF in this process according to Brönsted – Lowry theory.

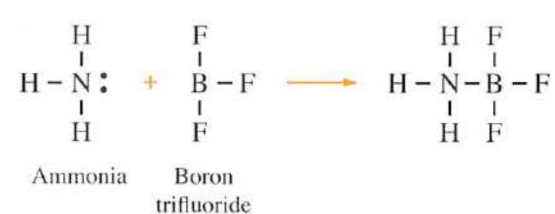
32 **In the following overall ionic equation :**

$$HC_2H_3O_{2(aq)} + Na^+_{(aq)} + OH^-_{(aq)} \rightleftharpoons Na^+_{(aq)} + C_2H_3O^-_{2(aq)} + H_2O_{(\ell)}$$

(1) Write the net ionic equation which represents this reaction.

(2) Determine the conjugate base in this reaction.

33 **Determine the acid and the base** in the reaction which is represented by the opposite equation.



New types of questions ? Answered

Choosing two out of five choices questions :

1 **Which of the following substances represent the different concepts of acids and bases ?**

(a) H_2O represents a Brönsted - Lowry base but not an Arrhenius base.

(b) KOH represents an Arrhenius base but not a Lewis base.

(c) NH_3 represents an Arrhenius base but not a Lewis base.

(d) H^+ represents a Lewis acid and Arrhenius acid.

(e) HSO_4^- represents an Arrhenius acid and a Brönsted - Lowry acid.

2 **Which of the following can act as an acid and as a base according to Brönsted - Lowry ?**

(a) CH_3COOH

(b) HS^-

(c) NO_3^-

(d) $H_2PO_4^-$

(e) OH^-

3 **Phosphine gas dissolves in water according to the reaction :**

$$PH_{3(g)} + H_2O_{(l)} \rightleftharpoons PH_4OH_{(aq)}$$

Which of the following matches lewis theory of acids and bases ?

(a) H_2O is the acid, as it accepts a lone pair of electrons from phosphine.

(b) H_2O is the acid, as it donates a lone pair of electrons to phosphine.

(c) PH_3 is the acid, as it accepts a lone pair of electrons from water.

(d) H_2O is the base, as it accepts a lone pair of electrons from phosphine.

(e) PH_3 is the base, as it donates a lone pair of electrons to water.

4 **In the reaction :** $HSO^-_{4(aq)} + NH_{3(g)} \rightleftharpoons SO^{2-}_{4(aq)} + NH^+_{4(aq)}$

Which of the following is correct ?

(a) NH_4^+ acts as a Lewis base.

(b) SO_4^{2-} acts as a Brönsted - Lowry base.

(c) NH_3 acts as a Lewis base.

(d) HSO_4^- acts as a Brönsted - Lowry base.

(e) NH_3 acts as an Arrhenius base.

Classification of acids

Acids can be classified according to :

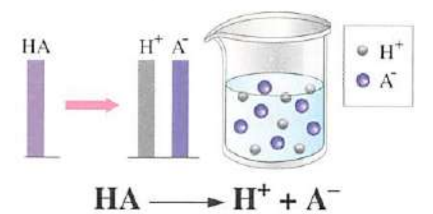
1. **Their strengths (degree of ionization).** 2. **Their sources.** 3. **Numbers of their basicity.**

1 Classification of acids according to their strengths (degree of ionization)

* **Acids are classified according to their degree of ionization in water into :**

Strong acids

Which are completely ionized in water



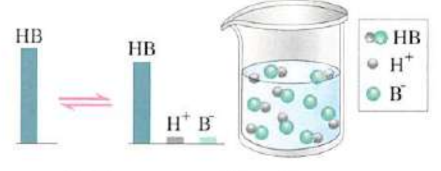
$$HA \longrightarrow H^+ + A^-$$

Strong acid

- Their aqueous solutions are good conductors of electricity.
- They are strong electrolytes.
- As all their molecules ionize in water.

Weak acids

Which are incompletely ionized in water



$$HB \rightleftharpoons H^+ + B^-$$

Weak acid

- Their aqueous solutions are bad conductors of electricity.
- They are weak electrolytes.
- As a small part of their molecules ionizes in water.

Examples

Strong acids:

- Perchloric acid $HClO_4$
- Hydroiodic acid HI
- Hydrochloric acid HCl
- Hydrobromic acid HBr
- Sulphuric acid H_2SO_4
- Nitric acid HNO_3

Weak acids:

- Carbonic acid H_2CO_3
- Phosphoric acid H_3PO_4
- Acetic acid CH_3COOH
- Formic acid.
- Citric acid.
- Oxalic acid.
- Lactic acid.

* There is no relation between the strength of the acid and the number of hydrogen atoms in its molecular structure.

e.g. Phosphoric acid (H_3PO_4) is weaker than nitric acid (HNO_3), although it contains greater number of hydrogen atoms.

Worked Example

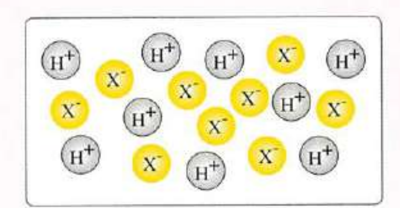
Write the chemical equation that expresses the ionization of acetic acid in water.

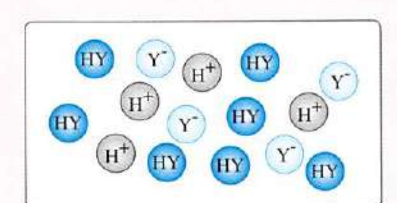
Answer :

$$\underset{\text{Acetic acid}}{CH_3COOH_{(aq)}} + H_2O_{(\ell)} \rightleftharpoons \underset{\text{Acetate ion}}{CH_3COO^-_{(aq)}} + \underset{\text{Hydronium ion}}{H_3O^+_{(aq)}}$$

Test Yourself

The two following figures show the ionization of each of HX and HY acids :





Which of the following statements represents these two acids ?

(a) They both are weak acids.

(b) They both are strong acids.

(c) HX acid is strong, while HY is weak.

(d) HX acid is weak, while HY is strong.

Answer : The correct choice is ....

2 Classification of acids according to their sources

* **Acids are classified according to their sources (origins) into :**

Organic acids	Mineral acids
• Acids that have an organic origin (plant or animal).	• Acids that have no organic origin.
i.e. They are extracted from the organs of living organisms.	i.e. They usually have a nonmetallic elements in their structures like chlorine, sulphur, nitrogen and phosphorus.
• All of them are weak acids.	• Some of them are strong acids and others are weak.
Examples	**Examples**
• Lactic acid (milk products). • Acetic acid (vinegar). • Citric acid (from citrus plants). • Oxalic acid. • Formic acid (from ants).	• Carbonic acid. • Hydrochloric acid. • Phosphoric acid. • Perchloric acid. • Nitric acid. • Sulphuric acid.

Included information

Organic acids are characterized by containing – COOH group which is known as carboxyl group

3 Classification of acids according to the number of basicity

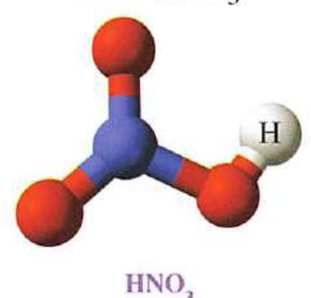
The basicity of acid is the number of hydrogen ions (H^+), which are produced by one molecule of the acid when it dissolves in water (the replaceable hydrogen atoms).

* **Acids are classified according to their basicity into :**

Monobasic acids (Monoprotic)	Dibasic acids (Diprotic)	Tribasic acids (Triprotic)
Acids where each molecule gives one proton H^+ when it dissolves in water	Acids where each molecule gives one or two protons H^+ when it dissolves in water	Acids where each molecule gives one, two or three protons H^+ when it dissolves in water

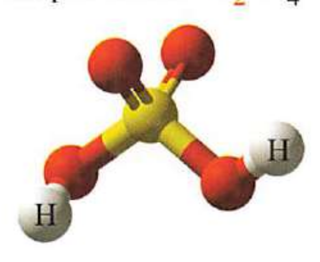
Examples

- **Organic monobasic acids :**
  - Formic acid HCOOH
  - Acetic acid CH_3COOH
- **Mineral monobasic acids :**
  - Hydrochloric acid HCl
  - Nitric acid HNO_3



HNO_3
Monobasic acid

- **Organic dibasic acids :**
  Oxalic acid COOH – COOH (COOH bonded to COOH)
- **Mineral dibasic acids :**
  - Carbonic acid H_2CO_3
  - Sulphuric acid H_2SO_4

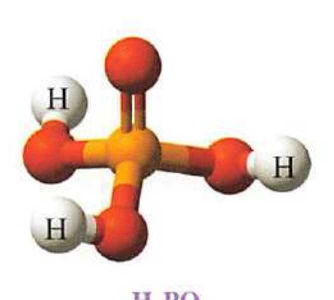


H_2SO_4
Dibasic acid

- **Organic tribasic acids :**
  Citric acid

$$\begin{array}{c} H_2C - COOH \\ | \\ HO - C - COOH \\ | \\ H_2C - COOH \end{array}$$

- **Mineral tribasic acids :**
  Phosphoric acid H_3PO_4



H_3PO_4
Tribasic acid

Worked Example

The salts of the opposite acid are used in medicine and dyeing of fabrics. What is the similarity between this acid and sulphuric acid ?

$$HOOC - \underset{OH}{\overset{H}{C}} - \underset{OH}{\overset{H}{C}} - COOH$$

ⓐ They both are dibasic.
ⓑ They both are organic acids.
ⓒ They both are strong acids.
ⓓ They both are mineral acids.

Idea of answering :

∵ The acid contains two (– COOH) groups. ∴ The acid is dibasic.

∵ Sulphuric acid is dibasic. ∴ They both are dibasic.

Answer : The correct choice is ⓐ

Classification of bases

* Bases can be classified according to :

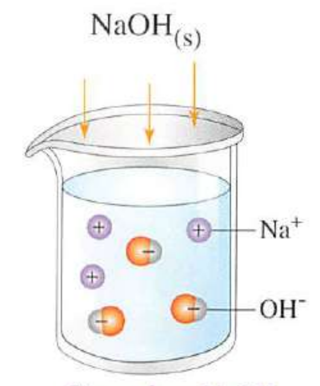
1. **Their strengths (degree of ionization or dissociation).**
2. **Their molecular structures.**

1 Classification of bases according to their strengths (degree of ionization or dissociation)

* **Bases are classified according to their degree of ionization (dissociation) into :**

Strong bases

Which are completely ionized in water

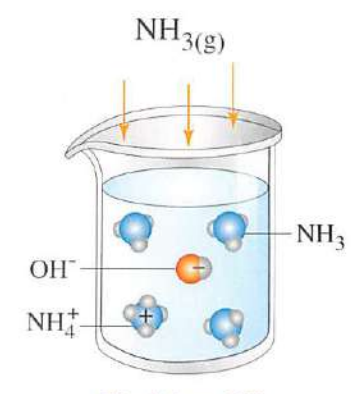


Strong base NaOH
1 mol of it dissociates in water yielding 1 mol of OH^- ions

- Their solutions are good conductors of electricity.
- They are strong electrolytes.
- As all their molecules dissociate in water into ions.

Weak bases

Which are incompletely ionized in water



Weak base NH_3
1 mol of it ionizes partially in water yielding very small number of OH^- ions

- Their solutions are bad conductors of electricity.
- They are weak electrolytes.
- As a small part of their molecules ionizes in water into ions.

Examples

Strong bases:

- Potassium hydroxide KOH
- Sodium hydroxide $NaOH$
- Barium hydroxide $Ba(OH)_2$

Weak bases:

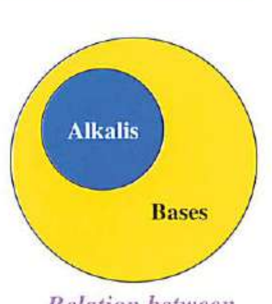
- Ammonium hydroxide NH_4OH

2 Classification of bases according to their molecular structures

* **Some substances react with acids forming salt and water, so these substances are considered as bases, as shown in the following table :**

Bases	Examples	Applications
1 Metals oxides	Iron (II) oxide FeO Magnesium oxide MgO	$FeO_{(s)} + 2HCl_{(aq)} \xrightarrow{dil.} FeCl_{2(aq)} + H_2O_{(l)}$ Iron (II) oxide, Hydrochloric acid, Iron (II) chloride, Water
2 Metals hydroxides	Calcium hydroxide $Ca(OH)_2$ Sodium hydroxide $NaOH$	$Ca(OH)_{2(aq)} + H_2SO_{4(aq)} \xrightarrow{dil.} CaSO_{4(s)} + 2H_2O_{(l)}$ Calcium hydroxide, Sulphuric acid, Calcium sulphate, Water
3 Metals carbonates	Potassium carbonate K_2CO_3 Sodium carbonate Na_2CO_3	$K_2CO_{3(s)} + 2HCl_{(aq)} \xrightarrow{dil.} 2KCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$ Potassium carbonate, Hydrochloric acid, Potassium chloride, Water, Carbon dioxide gas
4 Metals bicarbonates	Potassium bicarbonate $KHCO_3$ Sodium bicarbonate $NaHCO_3$	$KHCO_{3(s)} + HCl_{(aq)} \xrightarrow{dil.} KCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$ Potassium bicarbonate, Hydrochloric acid, Potassium chloride, Water, Carbon dioxide gas

* The base that dissolves in water is called Alkali which is the base that dissolves in water and gives hydroxide ion (OH^-).



Relation between alkalis and bases

So The alkalis are a part of the bases, and therefore we can say that :

All alkalis are bases, but not all bases are alkalis.

The detection of acids and bases

- The aqueous solutions are divided into three types, which are :
  - Acidic solutions.
  - Alkaline solutions.
  - Neutral solutions.

* There are two methods for identifying these solutions :

1 Indicators.

2 pH-meter.

1 Using indicators for identifying the aqueous solutions

Indicators are weak organic acids or bases, their colors change with the change of the solution (medium) type, this is attributed to the fact that the colour of the ionized indicator differs from that before ionization.

* **Indicators are used in :**
  - Identifying the type of solution (acidic, neutral, basic).
  - Determining the end point in titration processes between acids and bases.

* **The following table shows examples of some indicators and their colours in different media :**

Indicator	Colour in acidic medium	Colour in neutral medium	Colour in basic medium
Methyl orange	Red	Orange	Yellow
Phenolphthalein	Colourless	Colourless	Pink
Litmus	Red	Purple	Blue
Bromothymol blue	Yellow	Pale green	Blue

Worked Example

Colour of phenolphthalein changes with ....

(a) $HCl_{(aq)}$ (b) $KOH_{(aq)}$ (c) $H_2O_{(l)}$ (d) $NaCl_{(aq)}$

Idea of answering :

∵ **Phenolphthalein stays colourless in :**

- The acidic medium as HCl

∴ The choice (a) is excluded.

- The neutral media as NaCl and H_2O

∴ The choices (c) and (d) are excluded.

Answer : The correct choice is (b)

Enrichment information

Ant and bee bites have an acidic effect, and can be treated by using sodium bicarbonate (alkaline) solution, whereas those of the wasp and jelly fish have a basic effect and can be treated by using vinegar (dilute acetic acid)

2 Using the hydrogen exponent pH for identifying the aqueous solutions

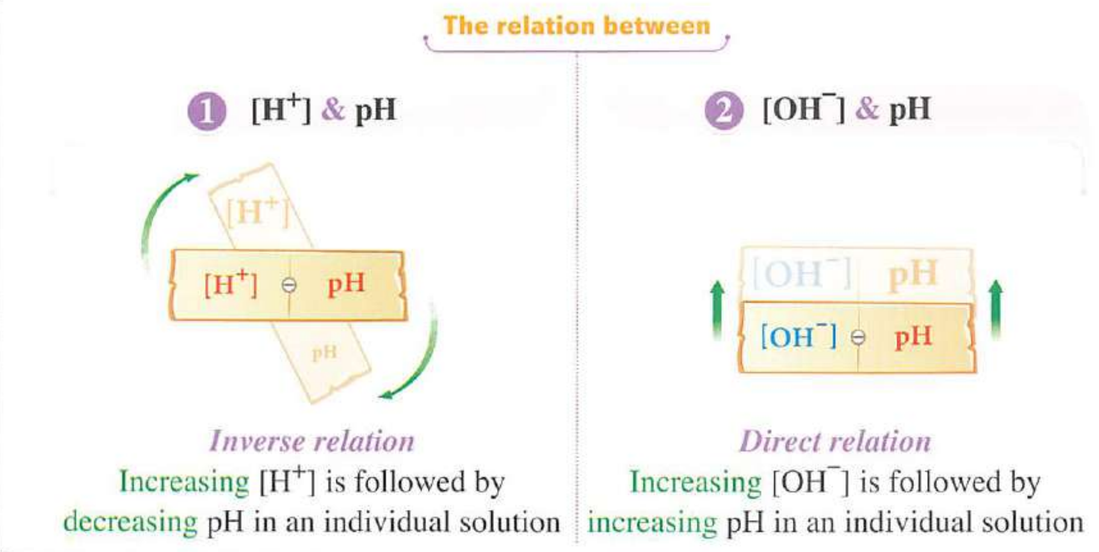
The hydrogen exponent pH is a way to express the degree of acidity or alkalinity of a solution.

pH-meter and pH paper tape

- The pH value is expressed by positive numbers range from (0 to 14).
- The pH value can be detected by :
  - The pH paper tape.
  - The pH-meter.
- The pH value depends on the concentration of :
  - Positive hydrogen ions (H^+).
  - Negative hydroxide ions (OH^-) in the solution, as follows :

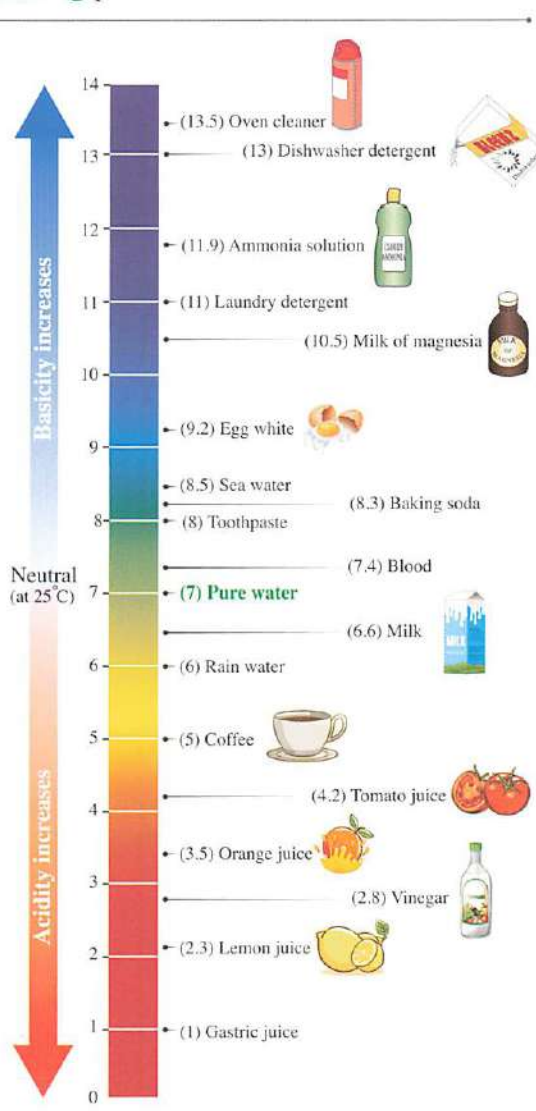
Acidic solution	Neutral solution	Basic solution
The concentration of $H^+ > OH^-$	The concentration of $H^+ = OH^-$	The concentration of $H^+ < OH^-$
pH value < 7	pH value = 7	pH value > 7
pH < 7	pH = 7	pH > 7

From the previous, it can be deduced that :



* **The opposite figure represents the pH - scale :**

- Vinegar, lemon and tomato juices are acidic substances (pH < 7), while pure water is a neutral substance (pH = 7).
- Baking soda, detergents, toothpaste , sea water and egg white (albumin) are basic substances (pH > 7).
- The strength of the acidic solution increases, as the value of pH approaches zero, while the strength of the basic solution increases, as the value of pH approaches 14



Test Yourself

Which of the solutions shown in the opposite table has the highest pH ?

Solution	(A)	(B)	(C)	(D)
H^+ concentration (mol/L)	0.1	0.01	0.001	0.0001

(a) A (b) B

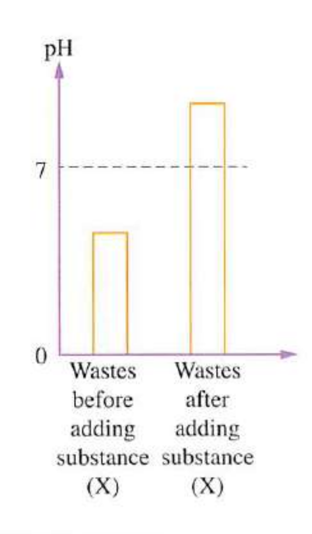
(c) C (d) D

Answer : The correct choice is ....

Worked Example

The opposite graphical figure represents pH values of the wastes of a factory before and after adding substance (X).

Which of these properties belongs to substance (X) ?



(a) It reacts with bases forming salt and water.

(b) H^+ ions concentration in it is higher than that of OH^- ions.

(c) It reacts with acids forming salt and hydrogen gas.

(d) It changes the colour of methyl orange indicator into yellow.

Idea of answering :

∵ Adding substance (X) to the wastes led to increasing pH above 7

∴ (X) is a base.

∴ The choices (a) and (b) are excluded.

∵ Bases react with acids forming salts and water (not hydrogen gas).

∴ The choice (c) is excluded.

Answer : The correct choice is (d)

Preliminary questions to remember the main concepts of the lesson

Answer them yourself

1 Choose the correct answer :

(1) Among the strong acids is ....

a. acetic acid.

b. carbonic acid.

c. nitric acid.

d. citric acid.

(2) All the following are mineral acids, except ....

a. sulphuric acid.

b. phosphoric acid.

c. citric acid.

d. hydrochloric acid.

(3) Which of the following represents the chemical formula of acetic acid as well as its origin ?

Choices	Formula	Origin
(a)	CH_3COOH	Mineral
(b)	CH_3COOH	Organic
(c)	$HCOOH$	Organic
(d)	H_3PO_4	Mineral

(4) All the following acids are monobasic, except ....

a. acetic acid.

b. oxalic acid.

c. nitric acid.

d. hydrochloric acid.

(5) All the following are properties of citric acid, except that it is a (an) ....

a. organic acid.

b. weak acid.

c. tribasic acid.

d. dibasic acid.

(6) All the following compounds are bases, except ....

a. Na_2CO_3

b. Na_2O

c. $NaNO_3$

d. NaOH

(7) The pH value of a strong basic solution is ....

a. 1

b. 5

c. 7

d. 13

(8) The solution whose pH value equals 1 is ....

a. strong alkali.

b. weak alkali

c. strong acid.

d. weak acid

2 Complete the following table :

	Indicator	The color in acidic medium	The color in basic medium	The color in neutral medium
(1)	Methyl orange	....	....	....
(2)	....	Yellow	....	....
(3)	....	....	....	Violet
(4)	....	....	Pink	....

Steady

Open book questions

Answered

Multiple choice questions

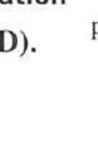
Classification of acids

1 Which of the following solutions that are equally concentrated has the highest ability to conduct electricity ?

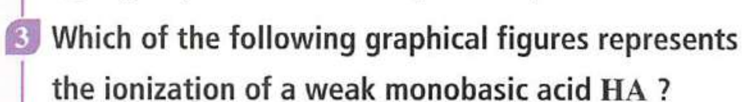
(a) H_2S
(b) H_2SO_4
(c) H_2SO_3
(d) H_2CO_3

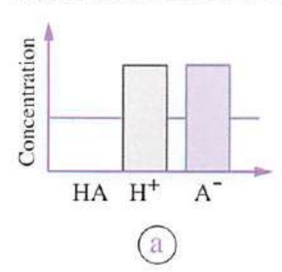
2 The test tube which contains sulphuric acid solution includes ....

(a) H_2SO_4 molecules only.
(b) H_2SO_4 molecules, HSO_4^- and H^+ ions.
(c) HSO_4^-, SO_4^{2-} and H^+ ions.
(d) H_2SO_4 molecules, HSO_4^- and SO_4^{2-} ions.

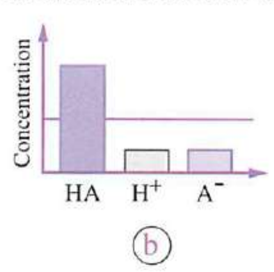


3 Which of the following graphical figures represents the ionization of a weak monobasic acid HA ?

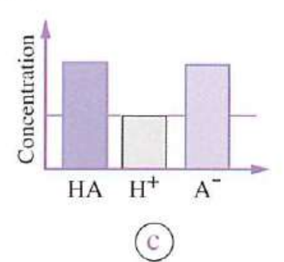




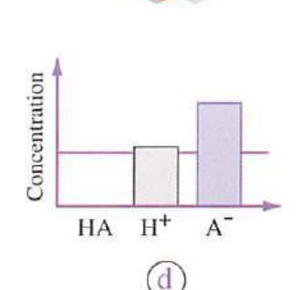
(a)



(b)



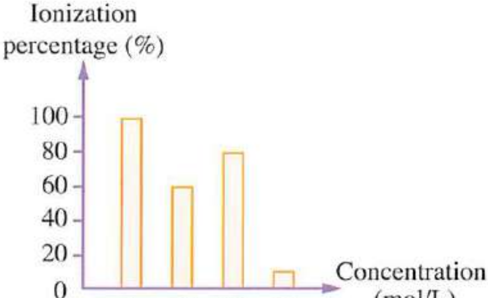
(c)



(d)

4 The opposite graph represents the ionization percentages of the acids (A), (B), (C) and (D). Which of these acids is an organic acid ?

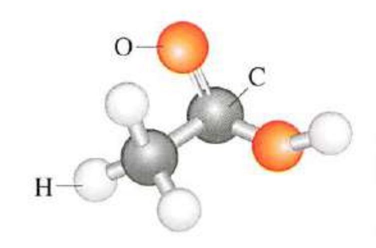
(a) A
(b) B
(c) C
(d) D



5 What is the acid whose molecule contains 4 hydrogen atoms only one of them is a replaceable hydrogen atom ?

(a) Sulphuric acid.
(b) Acetic acid.
(c) Formic acid.
(d) Oxalic acid.

6 **The acid which is illustrated in the opposite figure is classified as ....**

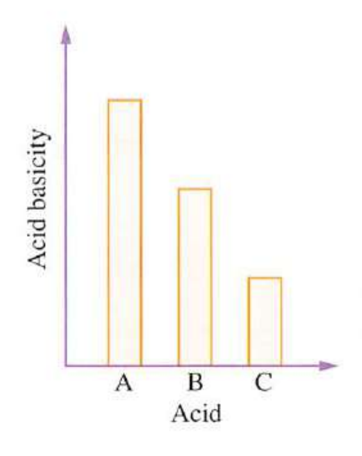


(a) a strong monobasic acid.
(b) a weak monobasic acid.
(c) a weak tribasic acid.
(d) a strong tribasic acid.

7 **What is the mass of the precipitate which is produced from the reaction of 96 g of magnesium with excess phosphoric acid ?** [Mg = 24 , P = 31 , O = 16]

(a) 24 g
(b) 48 g
(c) 240 g
(d) 349.3 g

8 **The opposite graphical figure represents the basicity of three acids, so if the acid (C) is hydroiodic acid. Which of the following represents the two acids (A) and (B) ?**



Choices	Acid (A)	Acid (B)
(a)	Sulphuric	Carbonic
(b)	Hydrochloric	Nitric
(c)	Citric	Carbonic
(d)	Carbonic	Acetic

9 **Which of the following is the correct ascending order of these acids according to the number of basicity ?**

(a) Phosphoric acid < Oxalic acid < Hydrocyanic acid.
(b) Oxalic acid < Hydrocyanic acid < Phosphoric acid.
(c) Hydrocyanic acid < Oxalic acid < Phosphoric acid.
(d) Oxalic acid < Phosphoric acid < Hydrocyanic acid.

Classification of bases

10 **Which of the following statements about acids and bases is correct ?**

(a) The base is a substance that donates positive hydrogen ions.
(b) The acid is a substance that accepts protons.
(c) The strong acid is almost 100% ionized.
(d) The weak acid does not react with strong bases.

11 Which of the following solutions has the highest ability to conduct electricity ?

(a) 0.1 M HCl (b) 1 M NaOH

(c) 2 M H_3PO_4 (d) 2 M C_2H_5OH

12 Which of the following is a monohydric base (contains one hydroxyl group) ?

(a) NH_4OH (b) HOH

(c) CH_3COOH (d) $Mg(OH)_2$

13 Which of the following includes weak acids and bases only ?

(a) $Ba(OH)_2$, CH_3NH_2 , CH_3COOH

(b) C_3H_7COOH , $CH_3CH_2NH_2$, HCOOH

(c) NH_3 , HNO_3 , CH_3CH_2COOH

(d) NH_3 , NaOH , H_2CO_3

14 Dissolution of the substance XH_3 in water is represented by the following equation :

$$XH_{3(aq)} + H_2O_{(l)} \rightleftharpoons XH^+_{4(aq)} + OH^-_{(aq)}$$

What is the type of the substance XH_3 ?

(a) Strong acid. (b) Strong base.

(c) Weak acid. (d) Weak base.

15 Which of the following substances its aqueous solution has the highest concentration of hydroxide ions ?

(a) PO_4^{3-} (b) NH_4^+ (c) HCO_3^- (d) H_2CO_3

16 Which of the following statements indicates that the substance (X) is an alkali ?

(a) When it dissolves in water, it yields positive hydrogen ions.

(b) It neutralizes acids forming salt and water, with the evolution of CO_2 gas.

(c) On heating (X) solution with ammonium chloride, NH_3 gas evolves.

(d) (X) solution reacts with acids and H_2 gas evolves.

17 Zinc hydroxide behaves in chemical reactions as an acid or as a base.
In which reaction of the following it behaves as an acid ?

(a) $Zn(OH)_2 + 2HCl \longrightarrow ZnCl_2 + 2H_2O$

(b) $Zn(OH)_2 + 2NaOH \longrightarrow Na_2ZnO_2 + 2H_2O$

(c) $3Zn(OH)_2 + 2H_3PO_4 \longrightarrow Zn_3(PO_4)_2 + 6H_2O$

(d) $Zn(OH)_2 + H_2SO_4 \longrightarrow ZnSO_4 + 2H_2O$

The detection of acids and bases

18 All the following are correct for ammonia solution, <u>except</u> that it ....

(a) is incompletely ionized.

(b) has pH value higher than 7

(c) has a boiling point less than that of pure water.

(d) is basic.

19 Which of the following represents the expected results of hydrochloric acid on adding sodium bicarbonate to it, as well as adding two drops of litmus indicator to another sample of it ?

Choices	Reaction with sodium bicarbonate	Formed colour with litmus
(a)	Reacts	Red
(b)	Reacts	Blue
(c)	No reaction	Red
(d)	No reaction	Blue

20 On reaching the neutralization point in a titration process, the colour changes from ....

(a) orange to red. (b) yellow to green.

(c) colourless to pink. (d) blue to red.

21 Which of the following indicators becomes yellow when it is added to a solution whose pH value is 10 ?

(a) Methyl orange. (b) Bromothymol blue.

(c) Phenolphthalein. (d) Litmus.

22 One of the chemical indicators which you have studied becomes yellow in the basic medium.

What is the colour that would appear in each of solution (A) whose pH is 3, and solution (B) whose pH is 7 ?

Choices	Colour in solution (A)	Colour in solution (B)
(a)	Red	Purple
(b)	Orange	Red
(c)	Red	Orange
(d)	Purple	Blue

23 Which of the following statements represents correctly a colourless solution with pH 9 ?

(a) H^+ ions concentration in it is higher than that of OH^- ions, and gives blue colour with litmus indicator.

(b) H^+ ions concentration in it is higher than that of OH^- ions, and gives orange colour with methyl orange.

(c) H^+ ions concentration in it is lower than that of OH^- ions, and gives blue colour with litmus indicator.

(d) H^+ ions concentration in it is lower than that of OH^- ions, and gives red colour with methyl orange.

24 On testing an aqueous solution with methyl orange and phenolphthalein indicators, they gave the results which are illustrated in the opposite table.

Indicator	Colour
Methyl orange	Yellow
Phenolphthalein	Pink

What is the approximate value of pH of this solution ?

(a) 6 (b) 7

(c) 2.7 (d) 11.7

25 Which of the following solutions contains the highest concentration of hydronium ions ?

(a) 1 M H_2CO_3 solution. (b) Pure water.

(c) 1 M HCl solution. (d) 1 M NH_3 solution.

26 The following table shows data about three different indicators :

Indicator	The colour at (pH = 1)	pH value at which the colour changes	The colour at (pH = 12)
(X)	Red	3	Yellow
(Y)	Red	5	Blue
(Z)	Colourless	10	Pink

, so if the liquid (W) yields a yellow solution with the indicator (X), a blue solution with (Y) and it yields a pink solution with (Z).

Which of the following statements represents the liquid (W) ?

(a) Pure water. (b) Hydrochloric acid solution.

(c) Its pH is 3 at least. (d) Sodium hydroxide solution.

27 **Which of the following is a property of the weak acidic aqueous solution only ?**

(a) It changes the colours of all chemical indicators.

(b) It has pH value less than 7 and higher than 2

(c) It reacts with ammonium salts forming ammonia gas.

(d) It reacts with all bases forming salt and water only.

28 **Which of the following - equally concentrated solutions - has the lowest pH value ?**

(a) Ammonia solution.

(b) Acetic acid solution.

(c) Lithium hydroxide solution.

(d) Nitric acid solution.

29 **pH value of 0.1 M NaOH solution = ...**

(a) 0.1

(b) 1

(c) 8

(d) 13

30 **On adding distilled water to a test tube contains sulphuric acid whose pH value = 2, it is possible that pH of the dilute solution becomes ....**

(a) 2

(b) 3

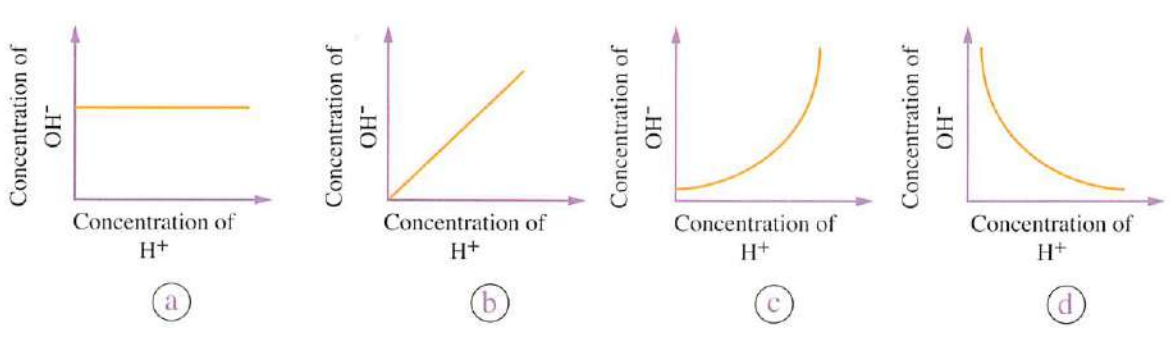
(c) 7

(d) 8

31 **The concentration of H^+ ions in formic acid differs from that in hydrochloric acid, and also their pH values are different when they are equally concentrated. Which of the following expresses formic acid compared to hydrochloric acid ?**

Choices	H^+ ions concentration	pH value
(a)	Higher	Higher
(b)	Higher	Lower
(c)	Lower	Higher
(d)	Lower	Lower

32 What is the graphical figure which represents correctly the relation between the concentration of H^+ ions, and that of OH^- ions in the same aqueous solution at constant temperature ?



33 Which of the following statements represents correctly two solutions of sodium hydroxide and ammonia that have equal volumes and concentrations ?

Sodium hydroxide solution ....

(a) has lower ability to conduct electricity than ammonia solution.

(b) contains H^+ ions concentration higher than that in ammonia solution.

(c) has pH value higher than that of ammonia solution.

(d) contains OH^- ions concentration lower than that in ammonia solution.

34 On adding drops of methyl orange indicator to each of (X) and (Y) solutions, the colour of (X) becomes red, while that of (Y) becomes yellow.

Which of the following represents both the pH value, and H^+ concentration in solution (X) relative to solution (Y) ?

Choices	pH value of solution (X) is lower than that of solution (Y)	H^+ concentration in solution (X) is lower than that in solution (Y)
(a)	✓	✓
(b)	✓	✗
(c)	✗	✓
(d)	✗	✗

Essay questions

Classification of acids

35 In the opposite table :
Which of the two acids (X) , (Y) represents a monobasic weak acid ?
Explain.

Acid	Before dissolving in water	After dissolving in water
(X)		
(Y)		

36 Formic acid was extracted for the first time from ants, so it is called formic (formica in latin means ants) :

(1) Why is formic acid an organic acid ?

(2) Is the aqueous solution of formic acid a good electrical conductor ? Explain.

37 Periodic acid is a weak acid, while perchloric acid is a strong acid :

$HO-ClO_3$ (HO – Cl with three =O) $HO-IO_3$ (HO – I with three =O)

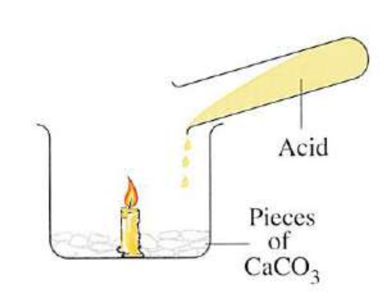
(1) Write the empirical formula of perchloric acid.

(2) Mention a similarity between the two acids.

Classification of bases

38 The opposite figure represents an experiment that is carried out using two different acids, which are :
- (1 M) HCl acid.
- (1 M) CH_3COOH acid.

Which of the two acids would result in faster extinguishing of the candle flame ? Give reason.



39 The opposite figure represents the dissolution of MOH in water :

(1) Which theory of those which describe acids and bases can explain the behaviour of the substance MOH in water ?

(2) What is the difference between the aqueous solution of the substance MOH and that of ammonium hydroxide ?

40 These are 3 positive ions and 5 negative ions :

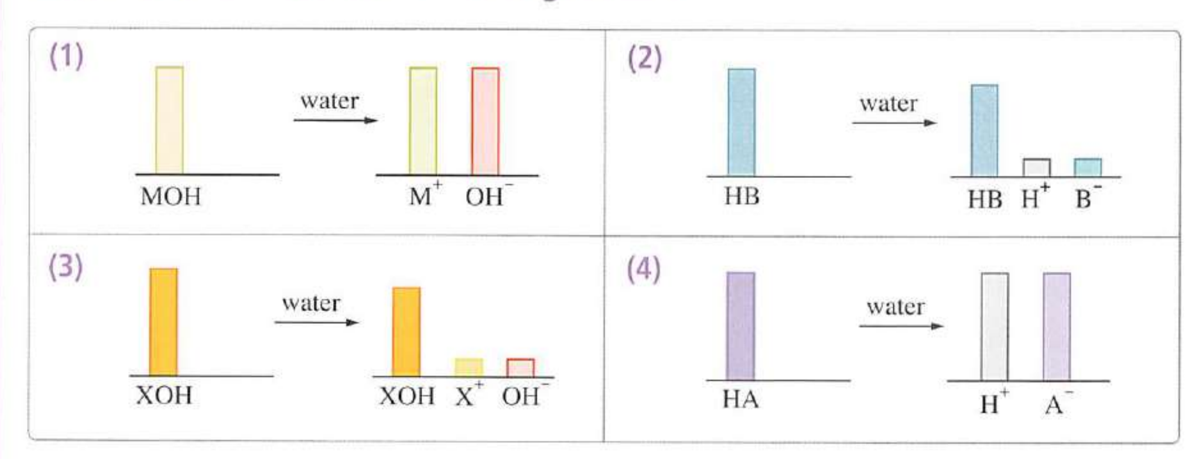
Positive ions	Negative ions
H^+ , K^+ , NH_4^+	SO_4^{2-} , CH_3COO^- , CO_3^{2-} , OH^- , NO_3^-

Use the previous ions to write the chemical formulas of the following compounds :

(1) Organic acid.
(2) Weak base.
(3) Strong dibasic mineral acid.
(4) Strong base.
(5) Monobasic mineral acid.
(6) Weak dibasic mineral acid.

The detection of acids and bases

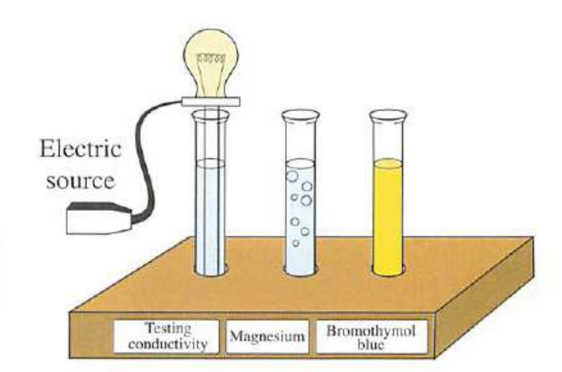
41 The following figures represent the change in the concentrations of 4 compounds which are acids and bases on dissolving in water :



Write the number of the figure which represents the ionization of :

(1) Ammonia solution.
(2) A compound whose pH = 1
(3) The compound which reacts slowly with magnesium.
(4) A compound whose pH = 13

42 The opposite figure represents three experiments carried out on one solution whose concentration is 1 M to test its electrical conductivity, as well as its reactivity with magnesium and the colour which it gives with bromothymol blue indicator :



(1) Is this solution acidic or basic ?
How can this be indicated ?

(2) Is this solution strong or weak ? How can this be indicated ?

New types of questions ? Answered

Choosing two out of five choices questions :

1 **Which of the following acidic substances is polyprotic ?**

(a) CHO_2 (b) NH_4^+ (c) H_3PO_4

(d) HCOOH (e) $C_2H_2O_4$

2 **Phosphoric acid resembles citric acid in that they both are ....**

(a) strong acids. (b) organic acids.

(c) weak acids. (d) mineral acids. (e) triprotic acids.

3 **Which of the following is an ion formed from the ionization of a monoprotic acid ?**

(a) HS^- (b) NO_3^- (c) HCO_3^-

(d) $H_2PO_4^-$ (e) CH_3COO^-

4 **Both iron (II) oxide and calcium oxide are ....**

(a) bases.

(b) alkalis.

(c) react with acids forming salt and water.

(d) react with acids and hydrogen gas evolves.

(e) nonmetal oxides.

5 **The colour of phenolphthalein does not change in the two solutions ....**

(a) KOH (b) HCl (c) NaCl

(d) $KHCO_3$ (e) NH_4OH

6 **The chemical indicator (X) is added to a solution its pH is 5.6**
Which of the following can be the chemical indicator (X) ?
What is the colour which the indicator gives in this solution ?

(a) Methyl orange and gives yellow colour.

(b) Phenolphthalein and gives pink colour.

(c) Litmus indicator and gives red colour.

(d) Bromothymol blue and gives yellow colour.

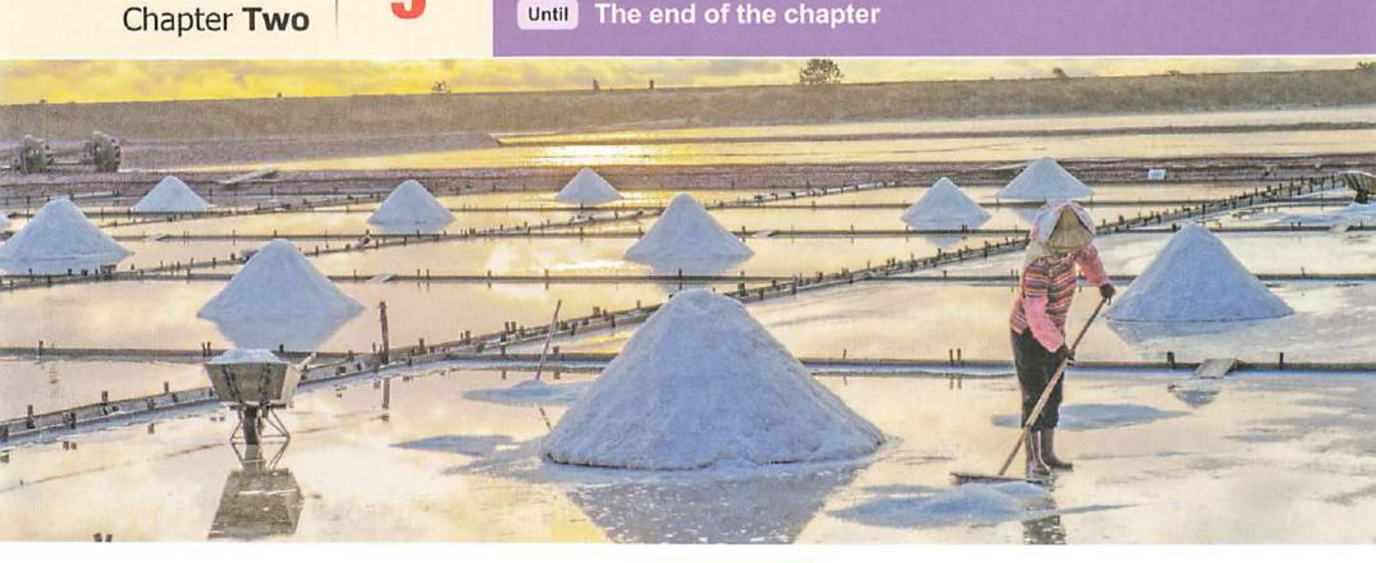
(e) Litmus indicator and gives purple colour.

Chapter **Two**

Lesson **3**

From Salts

Until The end of the chapter



Salts

Salts are found abundantly in earth's crust

They are also found dissolved or precipitated in sea water

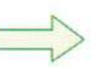
Salt formation : Any salt is formed of two radicals, as follows :

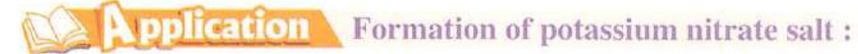
Cation M^+

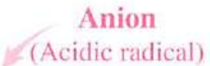
A positive ion (M^+) of the base (basic radical)

Anion X^-

A negative ion (X^-) of the acid (acidic radical)







- When potassium hydroxide reacts with dil. nitric acid, potassium nitrate salt is produced :

$$\underset{\text{Potassium hydroxide}}{K^+OH^-_{(aq)}} + \underset{\text{Nitric acid}}{H^+NO^-_{3(aq)}} \xrightarrow{\text{dil.}} \underset{\text{Potassium nitrate}}{K^+NO^-_{3(aq)}} + \underset{\text{Water}}{H_2O_{(l)}}$$

The chemical formulas of salts and their naming

- There are some rules should be considered during writing the formulas of the salts and naming them, as shown in the following table :

Rule	Application
• Pronouncing the chemical name of the mineral salt doesn't differ from the organic salt, **as follows :** – The chemical name of any salt is formed from two parts. – The first part refers to the basic radical (cation), while the second part refers to the acidic radical (anion). • Writing the chemical formula of mineral salt differs from that of organic salt : – In case of mineral salt the basic radical is written firstly, then the acidic radical. – In case of organic salt the acidic radical is written firstly, then the basic radical.	*Salt of mineral acid*: Basic radical → Potassium → K^+; Acidic radical → nitrate → NO_3^-; KNO_3 **Salt name** / **Chemical formula** *Salt of organic acid*: Basic radical → Potassium; Acidic radical → acetate; CH_3COO^- K^+; CH_3COOK
• If the salt contains hydrogen in its acidic radical, we have to add either : – (bi) or (hydrogen) before the name of its acidic radical.	Na^+ HSO_4^- Sodium bisulphate **or** Sodium hydrogen sulphate
• In the case of metals that have more than one valence, we have to write a latin number which refers to the valence of the cation.	• $Fe^{2+}SO_4^{2-}$ (Iron is divalent) Iron (II) sulphate • $Fe_2^{3+}(SO_4)_3^{2-}$ (Iron is trivalent) Iron (III) sulphate

1	2	3	4	5	6	7
(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)

*** The chemical formula of the salt depends on :**

- The acid which represents the source of the anion.
- The valence of the anion and cation.

The acid	Anion +	Cation ⟹	Salt	
HNO_3 Nitric acid	NO_3^- Nitrate anion	K^+	Potassium nitrate KNO_3	Nitrate Salts
		Pb^{2+}	Lead (II) nitrate $Pb(NO_3)_2$	
		Fe^{3+}	Iron (III) nitrate $Fe(NO_3)_3$	
HCl Hydrochloric acid	Cl^- Chloride anion	Na^+	Sodium chloride NaCl	Chloride Salts
		Mg^{2+}	Magnesium chloride $MgCl_2$	
		Al^{3+}	Aluminum chloride $AlCl_3$	
CH_3COOH Acetic acid	CH_3COO^- Acetate anion	K^+	Potassium acetate CH_3COOK	Acetate Salts
		Cu^{2+}	Copper (II) acetate $(CH_3COO)_2Cu$	
		Fe^{3+}	Iron (III) acetate $(CH_3COO)_3Fe$	
H_2SO_4 Sulphuric acid	SO_4^{2-} Sulphate anion	Na^+	Sodium sulphate Na_2SO_4	Sulphate Salts
		Cu^{2+}	Copper (II) sulphate $CuSO_4$	
	HSO_4^- Bisulphate anion	Na^+	Sodium bisulphate $NaHSO_4$	Bisulphate Salts
		Al^{3+}	Aluminum bisulphate $Al(HSO_4)_3$	
H_2CO_3 Carbonic acid	CO_3^{2-} Carbonate anion	Na^+	Sodium carbonate Na_2CO_3	Carbonate Salts
		Ca^{2+}	Calcium carbonate $CaCO_3$	
	HCO_3^- Bicarbonate anion	Na^+	Sodium bicarbonate $NaHCO_3$	Bicarbonate Salts
		Mg^{2+}	Magnesium bicarbonate $Mg(HCO_3)_2$	

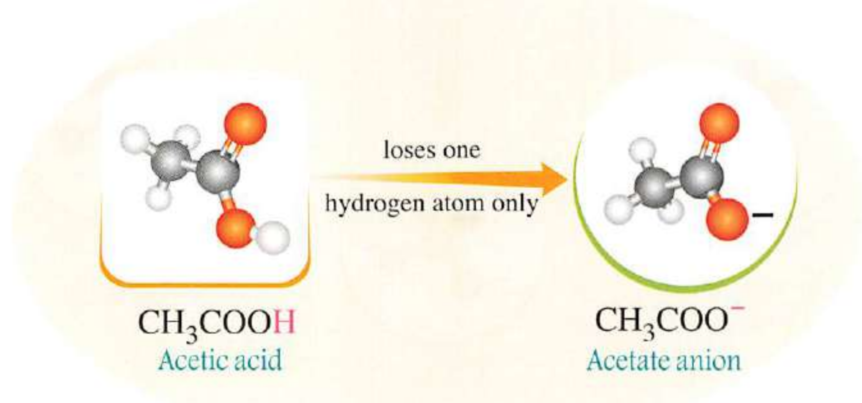
Note

$FeCl_3$ is called iron (III) chloride, while $AlCl_3$ is called aluminum chloride, although the valence of both iron and aluminum is 3 in both salts,
because iron has two valences (Fe^{2+} and Fe^{3+}), while aluminum is trivalent only (Al^{3+})

* **It is obvious from the previous table that :**
Some acids have more than one type of salts, basing on the number of the replaceable hydrogen atoms in the acid molecule, thus :

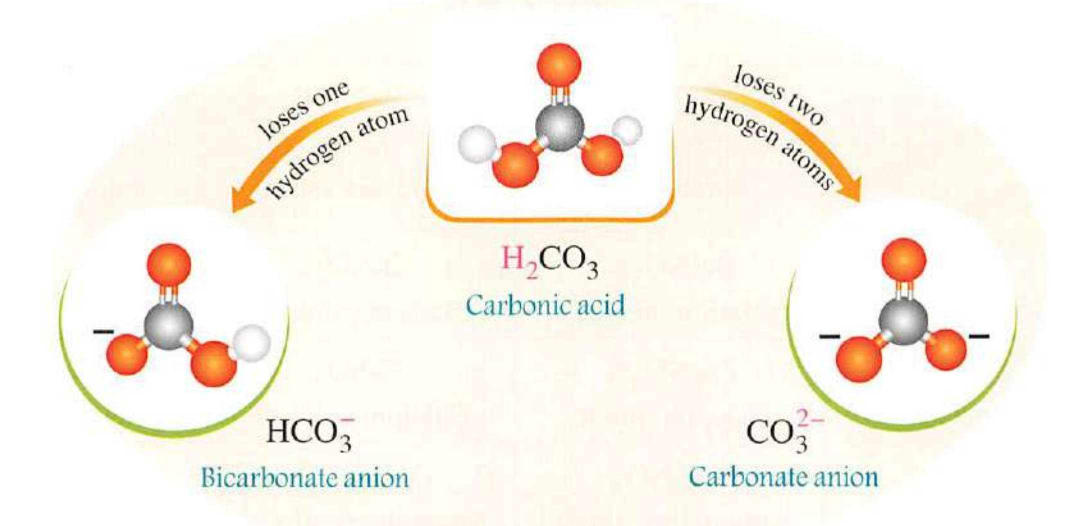
* **Monobasic acids form only one type of salts, as the molecule of each of them contains 1 replaceable hydrogen atom, such as :**

- Nitric acid HNO_3 ⟶ Forms nitrate salts only.
- Hydrochloric acid HCl ⟶ Forms chloride salts only.
- Acetic acid CH_3COOH ⟶ Forms acetate salts only.



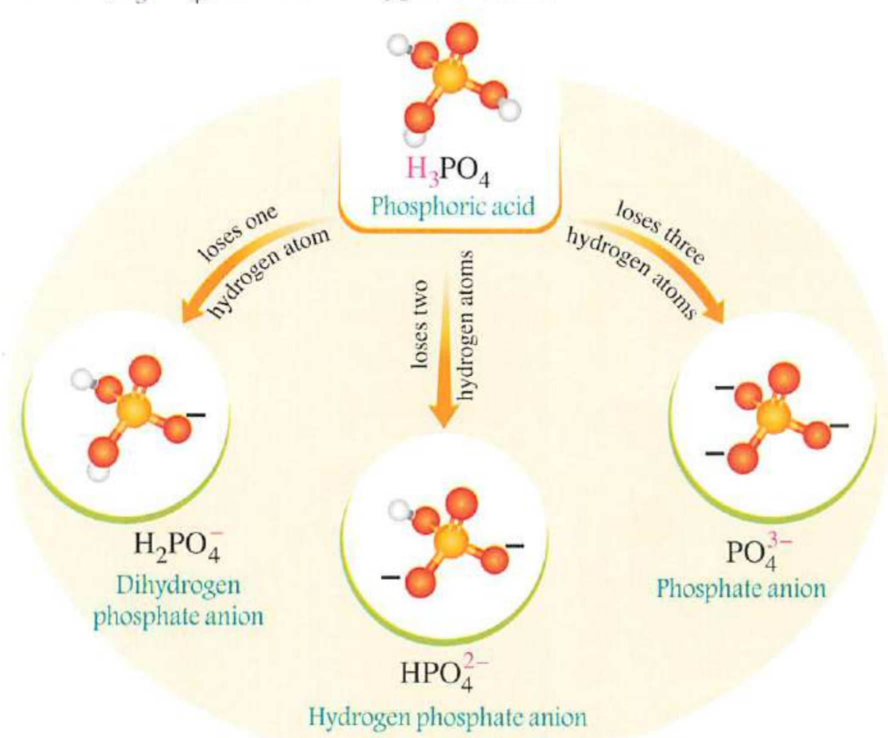
* **Dibasic acids form two types of salts, as the molecule of each of them contains 2 replaceable hydrogen atoms, such as :**

- Sulphuric acid H_2SO_4 ⟶ Forms bisulphate and sulphate salts.
- Carbonic acid H_2CO_3 ⟶ Forms bicarbonate and carbonate salts.



* **Tribasic acids form three types of salts, as the molecule of each of them contains 3 replaceable hydrogen atoms, such as :**

- Phosphoric acid (H_3PO_4) forms three types of salts :



Worked Example

Use the following acidic and basic radicals to write the chemical formulas of the salts produced by their combinations, then mention their names :

$$(Ba^{2+} \ / \ Ca^{2+} \ / \ NH_4^+ \ / \ NO_3^- \ / \ SO_4^{2-} \ / \ Cl^-)$$

Answer :

Acidic radical / Basic radical	NO_3^- Nitrate anion	SO_4^{2-} Sulphate anion	Cl^- Chloride anion
Ba^{2+} Barium cation	$Ba(NO_3)_2$ Barium nitrate	$BaSO_4$ Barium sulphate	$BaCl_2$ Barium chloride
Ca^{2+} Calcium cation	$Ca(NO_3)_2$ Calcium nitrate	$CaSO_4$ Calcium sulphate	$CaCl_2$ Calcium chloride
NH_4^+ Ammonium cation	NH_4NO_3 Ammonium nitrate	$(NH_4)_2SO_4$ Ammonium sulphate	NH_4Cl Ammonium chloride

Salt formation methods

* **Salts can be practically prepared by one of the following methods :**

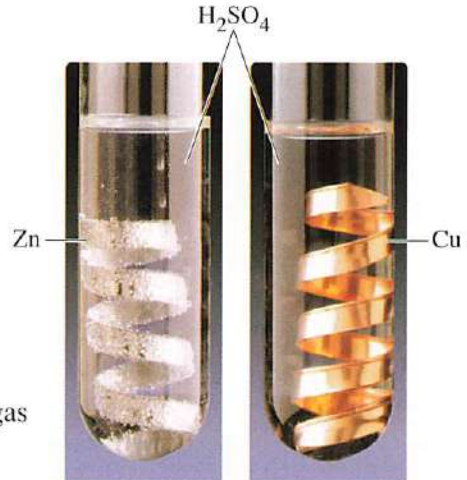
1. **Reaction of active metals with dilute acids.**
2. **Reaction of metals oxides with dilute acids.**
3. **Reaction of metals hydroxides with dilute acids.**
4. **Reaction of metals carbonates or bicarbonates with dilute acids.**

1 Reaction of active metals with dilute acids

Active metal + Acid $\xrightarrow{dil}$ Salt of acid + Hydrogen gas ↑

- The metals which lie above hydrogen in the chemical activity series **(remember)** replace hydrogen in the dilute acid solutions, giving salt of acid and hydrogen gas evolves which burns with a pop sound when a lit splint is exposed to it.

- If the produced salt of the acid dissolves in water, so it can be separated by heating the solution, where water evaporates and the salt remains.



Zinc reacts with dilute sulphuric acid while copper does not react with it

Application

Reaction of zinc with dilute sulphuric acid.

$$Zn_{(s)} + H_2SO_{4(aq)} \xrightarrow{dil} ZnSO_{4(aq)} + H_{2(g)}\uparrow$$

Zinc + Sulphuric acid → Zinc sulphate + Hydrogen gas

2 Reaction of metals oxides with dilute acids

Metal oxide + Acid $\xrightarrow{dil}$ Salt of acid + Water

- This method is used if there is a difficulty in the direct reaction of metal with acid, because :
  - The reaction is dangerous (e.g. reaction of sodium with hydrochloric acid is vigorous and causes an explosion).
  - The metal doesn't react with the acid, because it is less active than hydrogen (e.g. copper doesn't react with hydrochloric acid).

Application

Reaction of copper (II) oxide with dilute sulphuric acid.

$CuO_{(s)}$	+	$H_2SO_{4(aq)}$	$\xrightarrow{\text{dil}}$	$CuSO_{4(aq)}$	+	$H_2O_{(l)}$
Copper oxide		Sulphuric acid		Copper sulphate		Water

3 Reaction of metals hydroxides with dilute acids

Metal hydroxide (alkali) + Acid $\xrightarrow{\text{dil}}$ Salt of acid + Water

Titration process by using a suitable indicator

- This method is applicable for metal hydroxides which are soluble in water (alkalis) only.
- These types of reactions are known as **"neutralization reaction"**.
- Neutralization reaction can be used in analytical chemistry to estimate the unknown concentration of an acid (or a base) using a base (or an acid) with a known concentration in the presence of a suitable indicator.

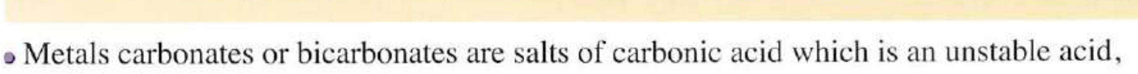
Neutralization point (end point) is the point at which the amount of acid is equivalent to the amount of alkali which is indicated by the change of the colour of the used chemical indicator.

Application

Neutralization of sodium hydroxide with dilute hydrochloric acid.

$NaOH_{(aq)}$	+	$HCl_{(aq)}$	$\xrightarrow{\text{dil}}$	$NaCl_{(aq)}$	+	$H_2O_{(l)}$
Sodium hydroxide		Hydrochloric acid		Sodium chloride		Water

4 Reaction of metals carbonates or bicarbonates with dilute acids



Metal carbonates (or bicarbonates) + Acid $\xrightarrow{\text{dil}}$ Salt of acid + Water + Carbon dioxide gas $\uparrow$

- Metals carbonates or bicarbonates are salts of carbonic acid which is an unstable acid, due to its low boiling point.
- It is possible for any other acid (that is more stable than it such as hydrochloric acid) to replace it in its salt solutions to form the salt of the stronger acid and the unstable carbonic acid.
- Carbonic acid decomposes in turn into water and carbon dioxide gas, which turns clear limewater milky after passing for short time in it.

Application

Reaction of sodium carbonate salt with dilute hydrochloric acid.

$$\underset{\text{Sodium carbonate}}{Na_2CO_{3(s)}} + \underset{\text{Hydrochloric acid}}{2HCl_{(aq)}} \xrightarrow{\text{dil}} \underset{\text{Sodium chloride}}{2NaCl_{(aq)}} + \underset{\text{Water}}{H_2O_{(l)}} + \underset{\text{Carbon dioxide gas}}{CO_{2(g)}\uparrow}$$

Note

The reaction of metal carbonates or bicarbonates with some acids is called "acidity test", because this reaction is used to detect the presence of the acids, as a strong effervescence occurs due to the evolution of CO_2 gas, which turns clear limewater turbid.

Types of aqueous solutions of salts

* The type of the salt solution depends on the acid and the base (alkali) forming it, as shown in the following table :

Base	+ Acid	⟹ Salt	Type of salt solution
NaOH (strong)	HCl (strong)	NaCl	Neutral pH = 7
NH_4OH (weak)	CH_3COOH (weak)	CH_3COONH_4	
NH_4OH (weak)	HCl (strong)	NH_4Cl	Acidic pH < 7
NaOH (strong)	H_2CO_3 (weak)	Na_2CO_3	Basic pH > 7

Applications

(1) The aqueous solution of potassium nitrate KNO_3 is neutral,

because KNO_3 is produced from the reaction of a strong acid (HNO_3) with a strong base (KOH). So the pH value is 7

(2) The pH value of an aqueous solution of ammonium acetate CH_3COONH_4 equals 7,

because this solution is neutral, where CH_3COONH_4 is produced from the reaction of a weak acid (CH_3COOH) with a weak base (NH_4OH).

(3) The pH value of an aqueous solution of ammonium chloride NH_4Cl is less than 7,

because this solution is acidic, where NH_4Cl is produced from the reaction of a strong acid (HCl) with a weak base (NH_4OH).

(4) The aqueous solution of sodium carbonate Na_2CO_3 is basic,

because Na_2CO_3 is produced from the reaction of a strong base (NaOH) with a weak acid (H_2CO_3). So its pH value > 7

Test Yourself

By using these ions :

$$[K^+ / NH_4^+ / SO_4^{2-} / HCOO^-]$$

Predict the chemical formula of the compound which dissolves in water forming :

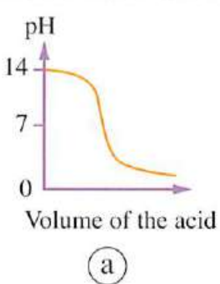
(1) A salt solution that increases the acidity of the soil. (...............)

(2) A salt solution that changes the colour of phenolphthalein. (...............)

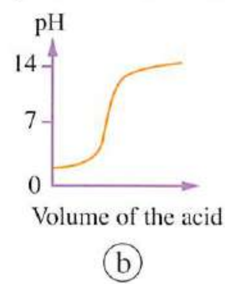
(3) A solution whose pH is 7 (............... , ...)

Worked Example

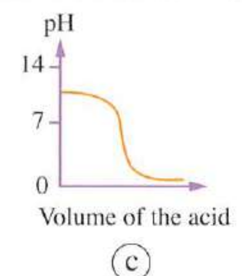
What is the curve which represents the titration of a weak base with a strong acid ?



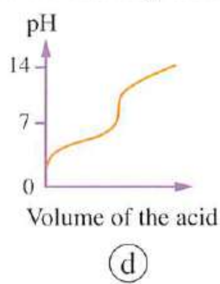
(a)



(b)



(c)



(d)

Idea of answering :

∵ The solution in the flask, before starting the titration process, is a weak base.

∴ Its pH is slightly higher than 7 (lower than 14).

Answer : The correct choice is (c)

Test Yourself

The solution with the highest pH value is produced from the neutralization of ....

(a) HCl with NH_4OH (b) HNO_2 with KOH

(c) HCl with Na_2CO_3 (d) HNO_3 with NaOH

Idea of answering :

HCl	NH_4OH	HNO_2	KOH	Na_2CO_3	HNO_3	NaOH
Strong acid	Weak base	Weak acid	Strong base	Weak base	Strong acid	Strong base

* pH value is the highest in the strong basic solutions produced from the neutralization of .... acid with .... base.

Answer : The correct choice is ....

Preliminary questions to remember the main concepts of the lesson

Answer them yourself

1 Choose the correct answer :

(1) The anion of sodium hydrogen carbonate salt is ....

a. HCO_3^- b. CO_3^{2-}

c. HSO_4^- d. SO_4^{2-}

(2) Which of the following acids forms three types of salts ?

a. Phosphoric acid. b. Carbonic acid.

c. Sulphuric acid. d. Nitric acid.

(3) Salts are formed when acids react with each of the following, except ....

a. alkalis. b. metals carbonates.

c. metals oxides. d. nonmetals oxides.

(4) Acids react with active metals and ....

a. NH_3 gas evolves. b. N_2 gas evolves.

c. CO_2 gas evolves. d. H_2 gas evolves.

(5) Copper (II) sulphate salt is not prepared from the reaction of sulphuric acid with ....

a. copper. b. copper (II) oxide.

c. copper (II) carbonate. d. copper (II) hydroxide.

(6) In the acidity test, the evolved gas is ....

a. H_2 b. O_2

c. CO_2 d. CO

(7) Which of the following salts dissolves in water forming an acidic solution ?

a. NH_4Cl b. NaCl

c. CH_3COONa d. Na_2CO_3

(8) The pH value of CH_3COONH_4 solution equals ....

a. zero
b. 3
c. 7
d. 14

(9) Which of the following salts has an alkaline effect on litmus indicator ?

a. NH_4Cl
b. K_2CO_3
c. $NaNO_3$
d. KCl

(10) On adding phenolphthalein to the aqueous solution of ammonium chloride salt, the color of the solution becomes ....

a. red.
b. colorless.
c. yellow.
d. blue.

2 Give reasons for :

(1) $FeCl_2$ is called iron (II) chloride, while $MgCl_2$ is called magnesium chloride, although the two cations in both salts are divalent.

(2) The pH value of the aqueous solution of ammonium carbonate equals 7

Open book questions

Answered

Multiple choice questions

Salts

1 $(NH_4)_2HPO_4$ salt is known as ....

(a) ammonia phosphate. (b) ammonium hydrogen phosphate.
(c) ammonium phosphate. (d) ammonium hydrogen phosphide.

2 Metal (M) ion combines with hydrogen phosphate group forming $MHPO_4$ salt. What is the formula of the chloride of this metal ?

(a) MCl (b) MCl_2
(c) M_2Cl_2 (d) MCl_3

3 If the chemical formula of one of the chromium salts is $Cr(NO_3)_3$, so what is the probable formula of the corresponding chromium oxide ?

(a) CrO (b) CrO_2
(c) Cr_2O_3 (d) Cr_3O_2

4 If the chemical formula of the metal M sulphate is $M_2(SO_4)_3$, so the chemical formula of this metal phosphate is ....

(a) $M(HPO_4)_2$ (b) $M_3(PO_4)_2$
(c) $M_2(PO_4)_3$ (d) MPO_4

5 Which of the following formulas of the salts of phosphoric acid is incorrect ?

(a) K_3PO_4 (b) $CaPO_4$
(c) NaH_2PO_4 (d) $MgHPO_4$

6 Which of the following sodium compounds is not a salt ?

(a) Sodium formate. (b) Sodium hydroxide.
(c) Sodium carbonate. (d) Sodium acetate.

7 Which of the following acids does not form acidic salts ?

(a) Nitric acid. (b) Carbonic acid.
(c) Hydrochloric acid. (d) Sulphuric acid.

Salt formation methods

8 In which of the following reactions a pipette and a burette are used in preparing the salt ?

(a) The reaction of calcium carbonate with nitric acid to form calcium nitrate.
(b) The reaction of copper (II) oxide with sulphuric acid to form copper (II) sulphate.
(c) The reaction of potassium hydroxide with hydrochloric acid to form potassium chloride.
(d) The reaction of zinc with hydrochloric acid to form zinc chloride.

9 Magnesium sulphate crystals are prepared from the reaction of dilute sulphuric acid with excess of magnesium oxide in two steps, which are ....

(a) decomposition and filtration. (b) decomposition and oxidation.
(c) neutralization and evaporation. (d) neutralization and oxidation.

10 Which of the following substances are used in the titration processes ?

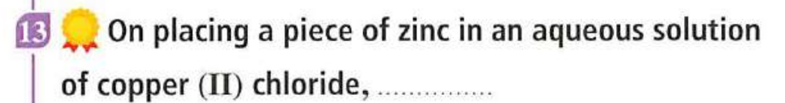
(a) An acid which is insoluble in water with a base which is insoluble in water.
(b) An acid which is insoluble in water with a base which is soluble in water.
(c) Water soluble acid with water insoluble base.
(d) Water soluble acid with water soluble base.

11 The opposite figure represents a chemical experiment, in which ....

(a) neutralization and precipitation processes take place.
(b) only neutralization process occurs.
(c) only precipitation process occurs.
(d) an oxidation-reduction process takes place.

12 19.2 mL of 0.1 M hydrochloric acid are added to 25 mL of sodium hydroxide solution in a titration process to estimate the concentration of sodium hydroxide solution. What are the tools required to measure the volumes of the two liquids accurately ?

Choices	Acid	Alkali
(a)	Burette	Graduated cylinder
(b)	Burette	Burette
(c)	Pipette	Graduated cylinder
(d)	Pipette	Burette



13 **On placing a piece of zinc in an aqueous solution of copper (II) chloride, ...**

(a) no change in the concentrations of the ions occurs.

(b) Cl^- ions concentration increases.

(c) Cu^{2+} ions concentration increases.

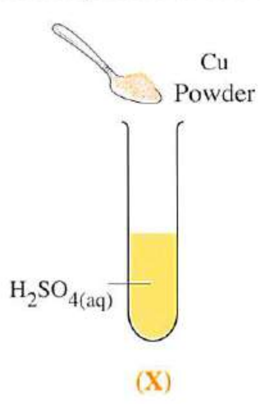
(d) Zn^{2+} ions concentration increases.

14 **Which of the following ions produces gas bubbles on adding hydrochloric acid to its solid salt ?**

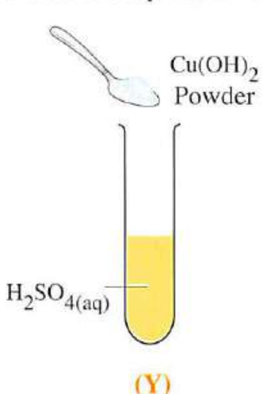
(a) Cu^{2+}　　(b) Fe^{3+}

(c) Al^{3+}　　(d) CO_3^{2-}

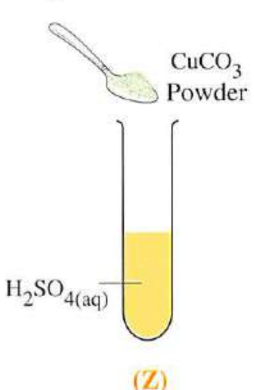
15 **The following figures represent three different experiments, during which three different powders are added to dilute sulphuric acid with stirring.**



(X)



(Y)



(Z)

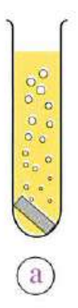
Which of these tubes contains $Cu^{2+}_{(aq)}$ ions ?

(a) X and Y only.　　(b) X and Z only.

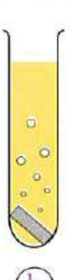
(c) Y and Z only.　　(d) X , Y and Z

16 **4 equal volumes of 0.1 M hydrochloric acid are added to 4 test tubes contain equal pieces of copper, iron, magnesium and zinc in no particular order.**

Which of these tubes contains copper metal ?



(a)



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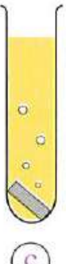

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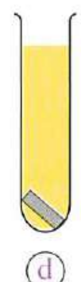


(d)

17 **Magnesium chloride can be prepared by the reaction of dilute hydrochloric acid with ....**

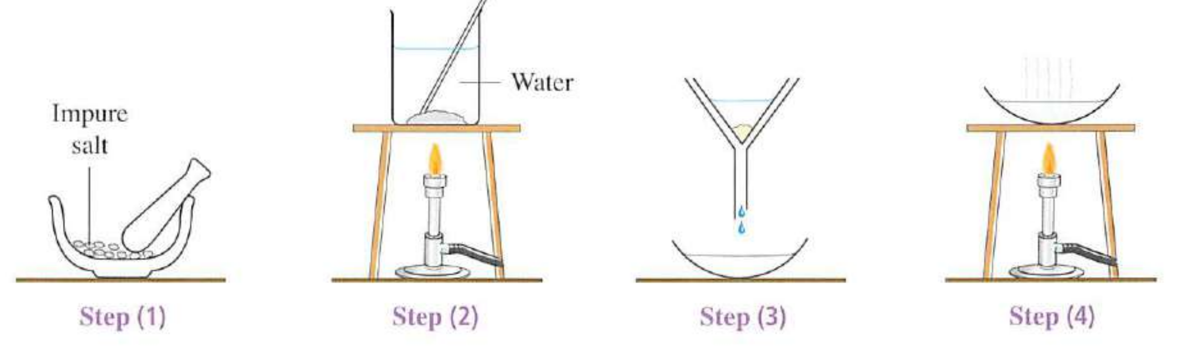
(a) magnesium carbonate or magnesium oxide only.

(b) magnesium or magnesium oxide only.

(c) magnesium or magnesium carbonate only.

(d) magnesium, magnesium carbonate or magnesium oxide.

18 **The following figures represent the steps of preparation of one of the salts :**



Which of the following salts can not be prepared by this method ?

(a) Barium sulphate.
(b) Copper (II) sulphate.
(c) Sodium sulphate.
(d) Sodium chloride.

Types of aqueous solutions of salts

19 **Acids are the main cause of the continuous corrosion of the teeth enamel, so calcium monophosphate $Ca(H_2PO_4)_2$ which is found in the teeth enamel is a(an) ....**

(a) basic substance.
(b) amphoteric substance.
(c) acidic substance.
(d) neutral substance.

20 **Which of the following substances dissolves in water forming 1 M solution which has the minimal pH value ?**

(a) Ammonium chloride.
(b) Ammonium acetate.
(c) Sodium acetate.
(d) Sodium chloride.

21 **The ions (K^+ / CN^- / Br^-) can produce two types of salts.**

Which of the following are the probable pH values of these two salts ?

(a) 3 and 5
(b) 7 and 12
(c) 3 and 7
(d) 9 and 11

22 The following solutions are equally concentrated.
What is the correct graduation of their pH values ?

(a) $NaCl < NH_4Cl < NaCN < HCl$
(b) $HCl < NH_4Cl < NaCl < NaCN$
(c) $NaCN < NH_4Cl < NaCl < HCl$
(d) $HCl < NaCl < NaCN < NH_4Cl$

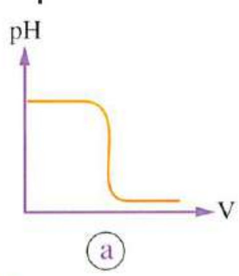
23 On mixing two equal volumes of H_2SO_4 and NaOH solutions, each of 1 M concentration, the produced solution ....

(a) is acidic.
(b) has pH = 7
(c) is alkaline.
(d) has pH > 7

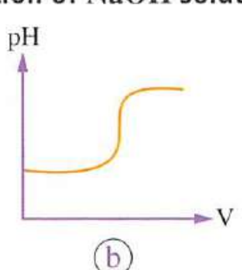
24 Among the well known ions are : (Cl^- / SO_4^{2-} / CH_3COO^- / K^+ / NH_4^+)
Which of the following two salts the pH values of their solutions are less than 7 ?

(a) NH_4Cl , CH_3COOK
(b) $(NH_4)_2SO_4$, NH_4Cl
(c) K_2SO_4 , KCl
(d) CH_3COONH_4 , K_2SO_4

25 What is the graphical figure which represents the process of the addition of NaOH solution to HCl solution ?



(a)



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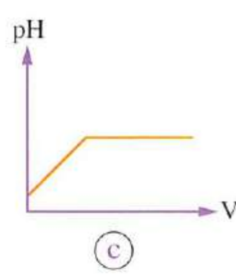
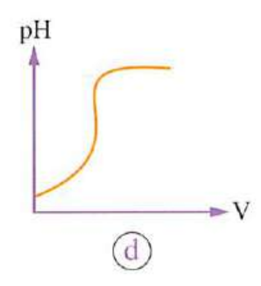


(c)



(d)

26 Which of the following salt solutions contains hydroxide ions in concentration higher than that of hydrogen ions ?

(a) $Ba(NO_3)_2$
(b) $NaClO_4$
(c) CH_3COOK
(d) $CuSO_4$

27 The value of pH of an aqueous solution of hydrochloric acid = 2
What is the value of pH of the solution which is produced from adding 10 g of NaCl to this acid ?

(a) pH = 1
(b) pH = 2
(c) pH = 7
(d) pH = 9

28 Passing or the dissolution of some compounds in pure water changes the pH value. Which of the following is incorrect ?

Choices	The substances added to water	The change in pH value
(a)	CO_2	Decreases below 7
(b)	Na_2CO_3	Rises above 7
(c)	NaCl	Rises above 7
(d)	NH_4Cl	Decreases below 7

29 **What is the solution which acquires red colour when drops of methyl orange are added to it ?**

(a) Sodium carbonate solution.

(b) Sodium chloride solution.

(c) Ammonium chloride solution.

(d) Potassium hydroxide solution.

Essay questions

Salt formation methods

30 **Write the balanced symbolic equation** which indicates the preparation of rubidium sulphate salt which is soluble in water using rubidium hydroxide RbOH which dissolves in water.

31 **Convert the following ionic equation into a symbolic equation :**

$$MgO_{(s)} + 2H^+_{(aq)} \longrightarrow Mg^{2+}_{(aq)} + H_2O_{(\ell)}$$

32 **The following compounds are used as fertilizers :**

$$[NH_4NO_3 - (NH_4)_3PO_4 - (NH_4)_2SO_4]$$

Which of these fertilizers does not affect the acidity of the soil ? Explain.

Types of aqueous solutions of salts

33 **What is the formed colour on adding drops of :**

(1) Bromothymol blue indicator to sodium chloride solution.

(2) Phenolphthalein indicator to sodium carbonate solution.

(3) Litmus indicator to ammonium acetate solution.

34 **How can you differentiate practically between :**

(1) Ammonium acetate solution and ammonium chloride solution "using methyl orange indicator".

(2) Ammonium nitrite solution, ammonium hydroxide solution and ammonium sulphate solution "using bromothymol blue indicator".

35 **Methylamine CH_3NH_2 is a weak base :**

(1) Write the equation of dissolving methylamine in water according to the concept of Brönsted-Lowry.

(2) What is the type of the salt which is produced from the reaction of methylamine with sulphuric acid ? Explain.

New types of questions ?

Choosing two out of five choices questions :

1 All the following are correct chemical formulas of the compounds, except ....

Choices	Compound	Chemical formula
(a)	Copper (II) nitrate	$Cu(NO_3)_2$
(b)	Calcium acetate	$(CH_3COO)_2Ca$
(c)	Aluminum sulphate	$Al(HSO_4)_3$
(d)	Magnesium carbonate	$MgCO_3$
(e)	Iron (II) fluoride	Fe_2F

2 The following solutions are equal in concentration, which of them is alkaline ?

(a) LiCl
(b) K_3PO_4
(c) $NaClO_4$
(d) NH_4NO_3
(e) HCOONa

3 The colour of litmus indicator does not change when it is added to ....

(a) LiF solution.
(b) $CrCl_3$ solution.
(c) KNO_3 solution.
(d) NH_4Cl solution.
(e) CH_3COONH_4 solution.

Exam model on Unit 3

Choose the correct answer for the questions

1 **What is the mass of NaOH (its molar mass = 40 g/mol) which is found in 500 mL of 0.175 M sodium hydroxide solution ?**

(a) 3.5 g

(b) 3.5×10^3 g

(c) 14 g

(d) 114 g

2 **All the following statements are correct, <u>except</u> ....**

(a) increasing temperature leads to increasing solubility of most of the solid substances.

(b) polar substances dissolve in organic solvents.

(c) nonpolar substances do not usually dissolve in water.

(d) the vapour pressure of the aqueous solution of Na_2SO_4 is lower than the vapour pressure of its pure solvent.

3 **Which of the following is formed by the dispersion of a gas in a liquid ?**

(a) Milk.

(b) Aerosol.

(c) Gel.

(d) Whipped cream.

4 **Which of the following choices represents the conjugate acid and the conjugate base of dihydrogen phosphate anion $H_2PO_4^-$?**

Choices	Conjugate acid	Conjugate base
(a)	HPO_4^{2-}	H_3PO_4
(b)	H_3PO_4	HPO_4^{2-}
(c)	H_3O^+	PO_4^{3-}
(d)	PO_4^{3-}	H_3O^+

5 Acetic acid CH_3COOH is different from sulphuric acid H_2SO_4 in that ....

(a) acetic acid is an organic acid, while sulphuric acid is a mineral acid.
(b) acetic acid is dibasic, while sulphuric acid is monobasic.
(c) acetic acid is a strong electrolyte, while sulphuric acid is a weak electrolyte.
(d) acetic acid is water insoluble, while sulphuric acid is water soluble.

6 According to the equation :

$$CaCO_{3(s)} + H_2SO_{4(aq)} \longrightarrow CaSO_{4(aq)} + H_2O_{(\ell)} + CO_{2(g)}$$

What is the volume of 0.5 M sulphuric acid which is required to react completely with 10 g of calcium carbonate ? [Ca = 40 , C = 12 , O = 16 , H = 1 , S = 32]

(a) 100 mL (b) 200 mL (c) 300 mL (d) 400 mL

7 What are the probable boiling and freezing points of an aqueous solution of sodium chloride ?

Choices	Boiling point	Freezing point
(a)	98°C	–2°C
(b)	98°C	2°C
(c)	102°C	–2°C
(d)	102°C	2°C

8 The following table illustrates the colour changes which occur on using 3 chemical indicators :

Indicator	Colour in low pH values	Colour in high pH values	pH range within which the colour changes
Methyl orange	Red	Yellow	3.2 : 4.4
Bromothymol blue	Yellow	Blue	6 : 7.6
Phenolphthalein	Colourless	Pink	8.2 : 10

On mixing 3 equal volumes of the previous indicators, and adding two drops of this mixture to a solution its pH is 6, the colour of the solution will be ....

(a) yellow.
(b) orange.
(c) green.
(d) blue.

9 **What is the name of the compound whose chemical formula is MnO_2 ?**

(a) Manganese (II) oxide. (b) Magnesium (II) oxide.

(c) Manganese (IV) oxide. (d) Magnesium (IV) oxide.

10 **When an acid reacts with an active metal, it produces the gas (X) which is collected by the method (2) that is illustrated in the opposite figure, and when an acid reacts with a carbonate salt, it produces the gas (Y) which is collected by the method (1). Which of the following represents the gases (X) and (Y) ?**

(Y) (X)
(1) (2)

(a) The gas (X) is hydrogen gas which is heavier than air.

(b) The gas (X) is hydrogen gas which is lighter than air.

(c) The gas (Y) is carbon dioxide gas which is lighter than air.

(d) The gas (Y) is carbon dioxide gas which is heavier than the gas (X) which is ammonia gas.

11 **The opposite figure represents one of the theories which describe acid and base :**

(A) + NH_3 ⇌ $[\ ]^+$ (B)

(1) Write the symbol of (A) and the formula of (B) which are represented in this figure.

....

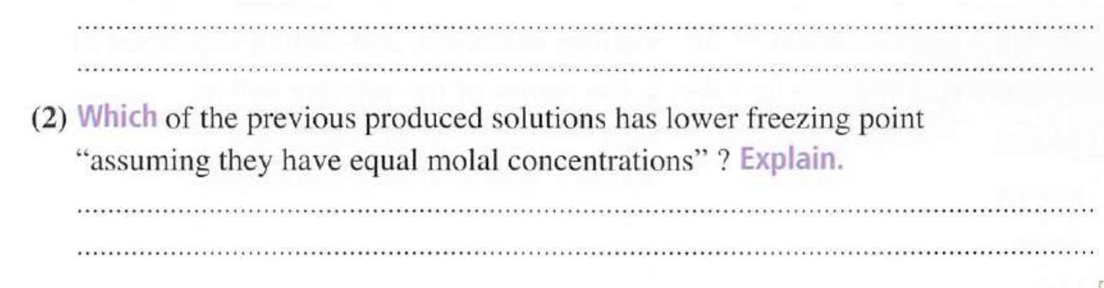
(2) Which of these two reactants represents the base ? **Explain.**

....

...... 2 marks

12 **Each of calcium carbonate and sodium bicarbonate salts reacts with dilute hydrochloric acid :**

(1) Write the symbolic equation which represents the reaction of each of them with the acid.



....

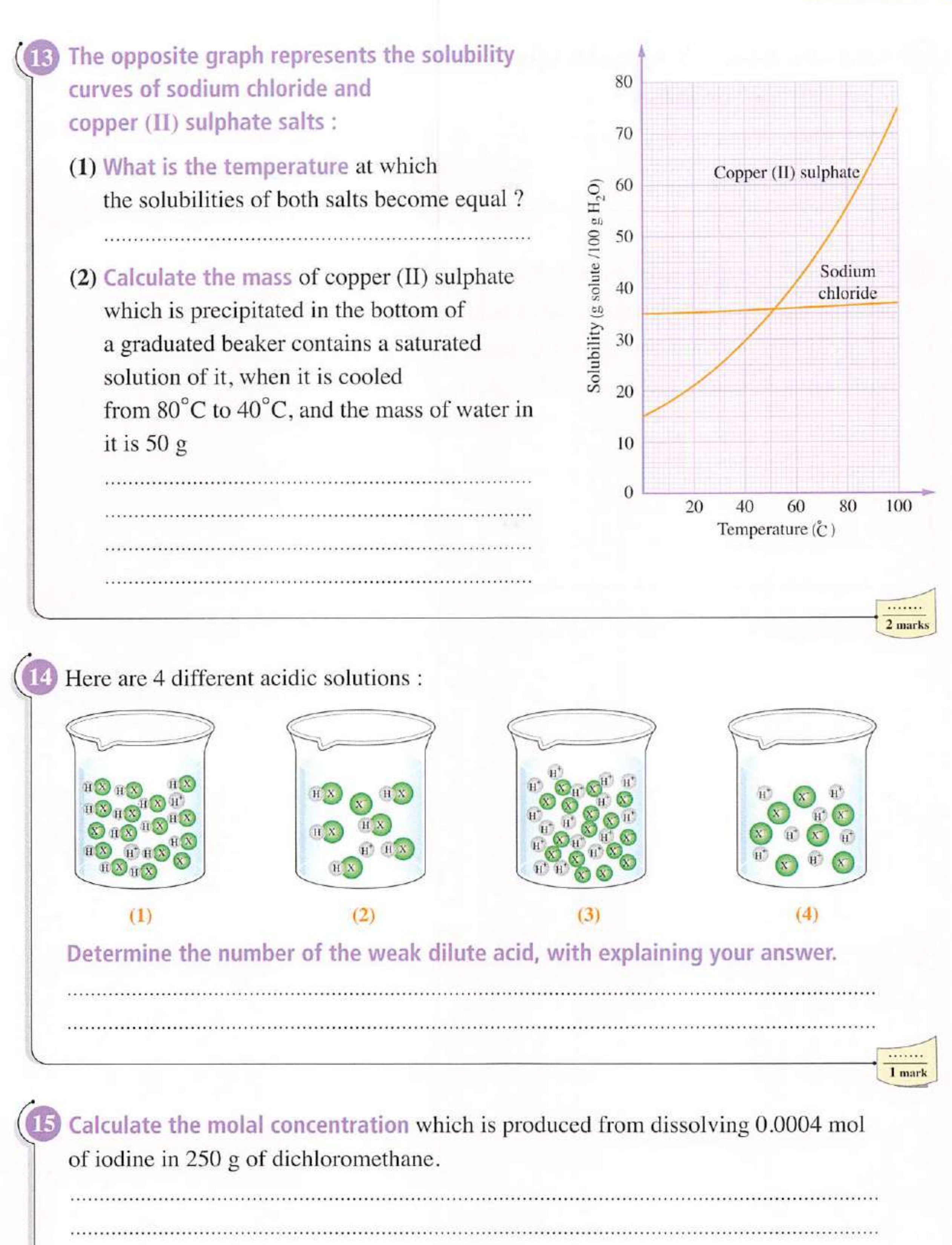
....

(2) Which of the previous produced solutions has lower freezing point "assuming they have equal molal concentrations" ? **Explain.**

....

....

...... 2 marks



13 The opposite graph represents the solubility curves of sodium chloride and copper (II) sulphate salts :

(1) What is the temperature at which the solubilities of both salts become equal ?

....

(2) Calculate the mass of copper (II) sulphate which is precipitated in the bottom of a graduated beaker contains a saturated solution of it, when it is cooled from 80°C to 40°C, and the mass of water in it is 50 g

....
....
....
....

.... 2 marks

14 Here are 4 different acidic solutions :

(1) (2) (3) (4)

Determine the number of the weak dilute acid, with explaining your answer.

....
....

.... 1 mark

15 Calculate the molal concentration which is produced from dissolving 0.0004 mol of iodine in 250 g of dichloromethane.

....
....
....

.... 1 mark

16 **Would you expect** zinc hydroxide to be used in manufacture of the glass cleaners or in car batteries ? **Explain.**

....

....

.... / 1 mark

17 **The opposite graph shows the relation** between the ionization percentage of an acid and its molar concentration, **does this graph represent a strong or a weak acid ? Explain.**

....

....

....

....

Ionization percentage (%)

5
4
3
2
1
0

0.02 0.04 0.06 0.08 0.10

Molar concentration (mol/L)

.... / 1 mark

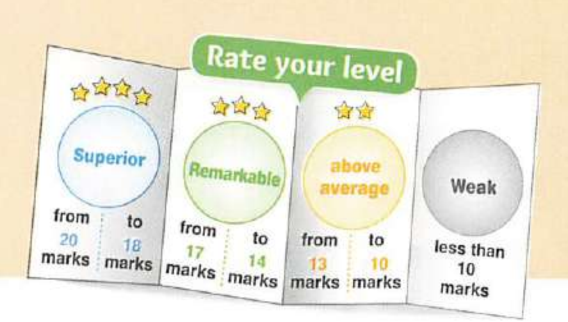
Open Book Exam Models

About the curriculum of the First Term

Answered

Open Book

Exam model 1

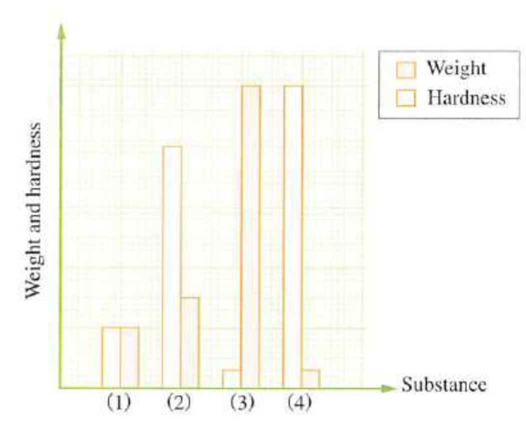


Choose the correct answer for the questions 1 : 9 .... 9 marks

1 Which of the following is not an Arrhenius acid ?

a) $H_2C_2O_4$ b) $H_2PO_4^-$
c) H_2O d) HNO_3

2 Which of the substances (1) : (4) in the opposite figure represents carbon nanotubes ?



a) (1)
b) (2)
c) (3)
d) (4)

3 These are 4 molecules of 4 different substances :

(1) Nitrogen molecule

(2) Ammonia molecule

(3) Hydrogen molecule

(4) Water molecule

Which of the following is correct ?

Choices	Polar molecule	Nonpolar molecule
a	(3)	(1)
b	(3)	(2)
c	(2)	(3)
d	(1)	(4)

4 All the following are Brönsted-Lowry bases, except ....

a) OH^- b) NH_4^+
c) NH_3 d) H_2O

5 Which of the following represents the weak acid and base ?

Choices	Weak acid	Weak base
a	H_2SO_4	NaOH
b	HNO_3	KOH
c	HCl	$Ca(OH)_2$
d	H_2CO_3	NH_4OH

6 Any organic compound (which is formed of carbon and hydrogen) can be burnt in pure oxygen forming carbon dioxide gas and water vapour.
What is the molecular formula of the organic compound which when burnt yields 1.5 mol of $CO_{2(g)}$ and 2 mol of $H_2O_{(v)}$?

a) C_2H_2
b) C_2H_4
c) C_3H_4
d) C_3H_8

7 You have two equal volumes of sodium hydroxide solution and ammonia solution, both have the same concentration.
Which of the following is true for these two solutions ?

a) The electrical conductivity of sodium hydroxide solution is less than that of ammonia solution.
b) H^+ ions concentration in sodium hydroxide solution is higher than that in ammonia solution.
c) pH value of sodium hydroxide solution is higher than that of ammonia solution.
d) OH^- ions concentration in sodium hydroxide solution equals that in ammonia solution.

8 Which of the following samples has the largest mass ? [N = 14 , H = 1]

a) 1 mol of N_2H_4
b) 2 mol of N_2
c) 3 mol of NH_3
d) 25 mol of H_2

9 The mass of one molecule of propanol C_3H_7OH equals .... [C = 12 , H = 1 , O = 16]

a) 60 g
b) 6.02×10^{23} g
c) 1×10^{-22} g
d) 3.6×10^{25} g

(10) Choose two correct answers :

Which of the underlined items in the following equations represents a Lewis acid ?

(a) $\underline{H_2O} + HPO_4^{2-} \rightleftharpoons H_2PO_4^- + OH^-$

(b) $H^+ + \underline{NH_3} \rightleftharpoons NH_4^+$

(c) $\underline{NO_2^-} + H_3O^+ \rightleftharpoons HNO_2 + H_2O$

(d) $NH_4^+ + \underline{HS^-} \rightleftharpoons H_2S + NH_3$

(e) $NH_3 + \underline{BF_3} \rightleftharpoons NH_3 + BF_3$

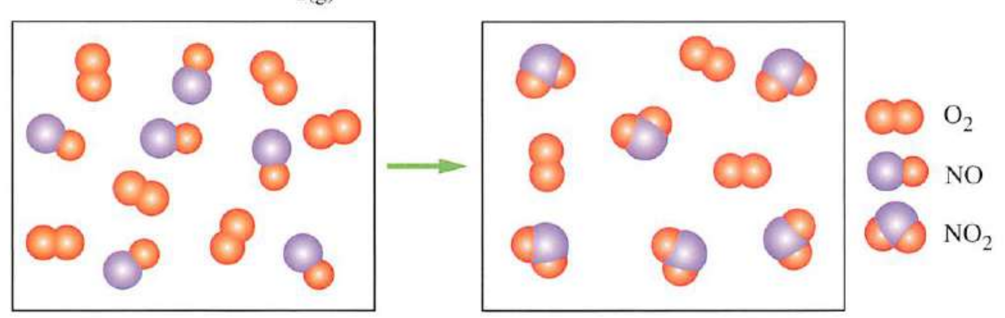
(11) The popular candy shown in the opposite figure is known as cotton candy.
is this candy :

(1) Homogeneous or heterogeneous mixture ?

(2) A solution, a suspension or a colloid ?

.... 1 mark

(12) The following figure illustrates the reaction of nitric oxide $NO_{(g)}$ with oxygen $O_{2(g)}$ to form nitrogen dioxide $NO_{2(g)}$:



Write the balanced symbolic equation which represents this reaction, **and determine** the limiting reactant of this reaction.

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13 You have a piece of an unknown metal.

How can you estimate the density of this metal ?

State the name and the importance of each of the used tools.

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.... 1 mark

14 Iron (III) oxide reacts with carbon monoxide according to the following reaction :

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

Complete the quantities required below the reactants and the products in the following equation when 0.5 mol of Fe_2O_3 undergoes the reaction : [Fe = 55.85 , O = 16 , C = 12]

Fe_2O_3	+	3CO	$\longrightarrow$	2Fe	+	$3CO_2$
0.5 mol		.......(1)...... g		........(2)..... atom		.......(3)..... L

.... 1 mark

15 **The opposite figure** shows the percentages of the components of a compound.

Calculate the molar mass of this compound, knowing that its molecular formula is its empirical formula as well.

[K = 39 , O = 16 , S = 32]

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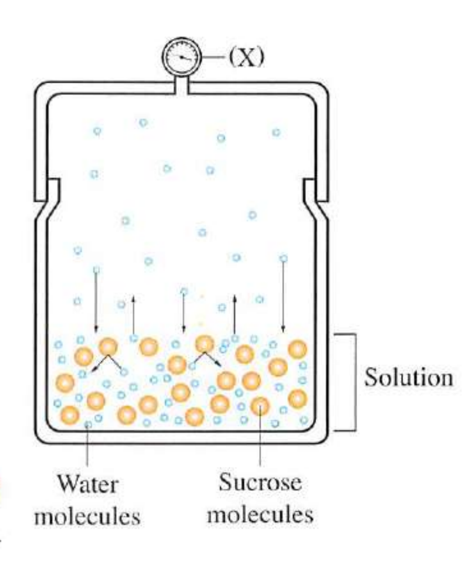
.... 1 mark



16 **The opposite figure shows the solution formed from adding 68.4 g of sucrose $C_{12}H_{22}O_{11}$ to 500 g of pure water :**

(1) **What** is the change in the reading of the device (X) which occurs after adding and dissolving sucrose in water ?

....

(2) **Calculate** the elevation or the depression of the freezing point which occurs after the complete dissolution of sucrose in water. [C = 12 , H = 1 , O = 16]

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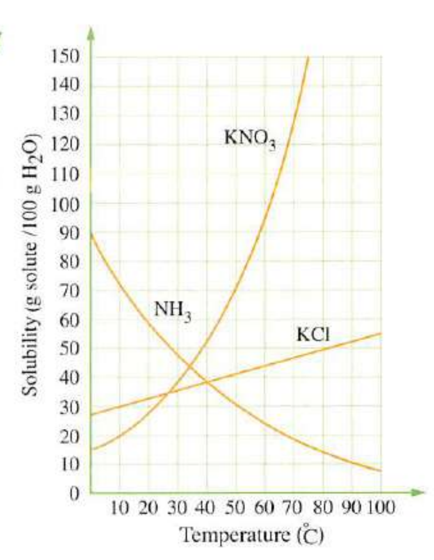
.... 2 marks



17 **The opposite graphical figure represents the solubility curve of three different substances :**

(1) **Calculate** the molal concentration of the saturated solution of KNO_3 at 70°C [K = 39 , N = 14 , O = 16]

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(2) **Compare** the effect of decreasing the temperature on the solubility between the solid substances and the gaseous substances in water.

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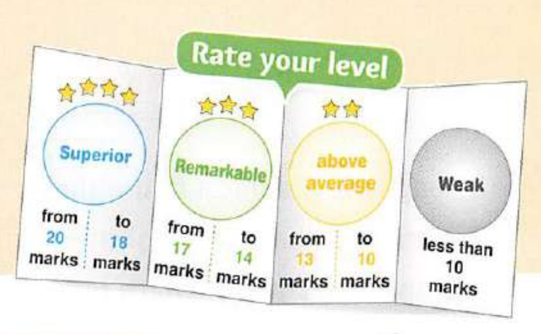
.... 2 marks

Open Book

Exam model 2



1 What is the branch of chemistry which is interested in the study of the process of separating a mixture of acetic acid and lactic acid, as well as the estimation of the percentage of each of them in the mixture ?

(a) Organic chemistry.
(b) Biochemistry.
(c) Analytical chemistry.
(d) Environmental chemistry.

2 Avogadro's number is symbolized by N_A

What is the number of the neutrons in 2.3 g of sodium $^{23}_{11}Na$?

(a) $1.2\ N_A$ (b) $1.1\ N_A$ (c) $2.3\ N_A$ (d) $23\ N_A$

3 Which of the following is not found in the aqueous solution of HCl ?

(a) H^+ (b) H_2O (c) Cl^- (d) HCl

4 What is the empirical formula of the metal (M) oxide if the mass percentage of oxygen in it is 40% ? [M = 24 , O = 16]

(a) M_2O
(b) MO
(c) M_2O_3
(d) M_2O_4

5 The reaction of copper (II) oxide with sulphuric acid is represented by the equation :

$$CuO_{(s)} + H_2SO_{4(aq)} \longrightarrow CuSO_{4(aq)} + H_2O_{(l)}$$

What is the ionic equation which represents this reaction ?

(a) $CuO_{(s)} + 2H^+_{(aq)} \longrightarrow Cu^{2+}_{(aq)} + H_2O_{(l)}$

(b) $Cu^{2+}_{(s)} + SO^{2-}_{4(aq)} \longrightarrow CuSO_{4(aq)}$

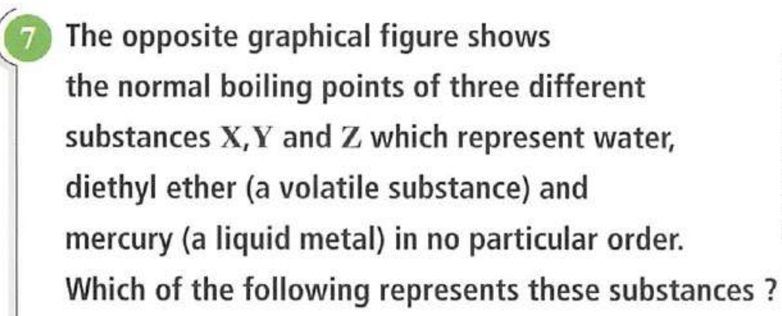
(c) $O^{2-}_{(s)} + H_2SO_{4(aq)} \longrightarrow H_2O_{(l)} + SO^{2-}_{4(aq)}$

(d) $CuO_{(s)} + H_2SO_{4(aq)} \longrightarrow Cu^{2+} + SO^{2-}_{4(aq)} + H_2O_{(l)}$

6 2 g of KNO_3 salt (its molar mass is 101 g/mol) are dissolved in a suitable amount of water to form a solution whose volume = 0.5 L

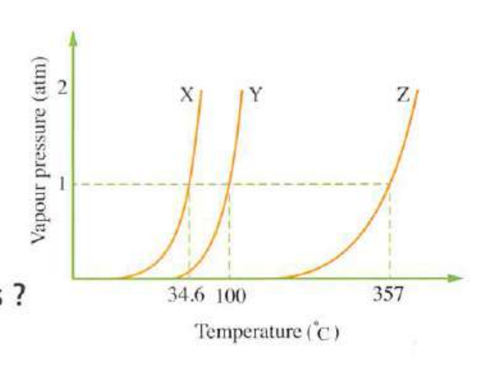
What is the molar concentration of the produced solution ?

(a) 0.02 M (b) 0.04 M (c) 0.1 M (d) 0.2 M



7 **The opposite graphical figure shows the normal boiling points of three different substances X, Y and Z which represent water, diethyl ether (a volatile substance) and mercury (a liquid metal) in no particular order.**

Which of the following represents these substances ?



(a) X represents water and Y represents mercury.

(b) Y represents water and Z represents diethyl ether.

(c) Y represents mercury and Z represents diethyl ether.

(d) X represents diethyl ether and Z represents mercury.

8 **There are two mixtures (X) , (Y) :**

- Mixture (X): Formed from sand and water.
- Mixture (Y): Formed from salt and water.

Which of the methods illustrated in the following table determines the most proper methods used in separating these components ?

Choices	Mixture (X)		Mixture (Y)	
	Obtaining the sand by	Obtaining water by	Obtaining the salt by	Obtaining water by
(a)	Crystallization	Distillation	Filtration	Filtration
(b)	Crystallization	Filtration	Filtration	Distillation
(c)	Filtration	Distillation	Crystallization	Filtration
(d)	Filtration	Filtration	Crystallization	Distillation

9 **The dyes which are extracted from the following plants can be used in preparing chemical indicators, except ....**

The plant	The original colour of the dye	The colour of the dye in lemon juice	The colour of the dye in sodium bicarbonate solution
(a)	Purple	Pink	Green
(b)	Green	Yellow	Yellow
(c)	Pink	Pink	Yellow
(d)	Yellow	red	Green

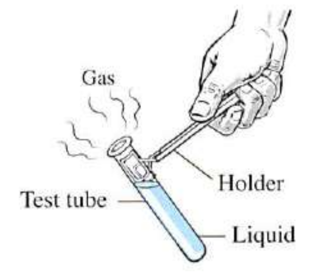
10 **Choose two correct answers :**

Which of the following pairs does not represent a conjugate acid and its base respectively ?

ⓐ NH_4^+ , NH_3 ⓑ HPO_4^{2-} , PO_4^{3-} ⓒ H_2O , OH^-

ⓓ SO_4^{2-} , HSO_4^- ⓔ Cl^- , HCl

11 **Determine one safety measure** upon performing the experiment which is illustrated in the opposite figure.



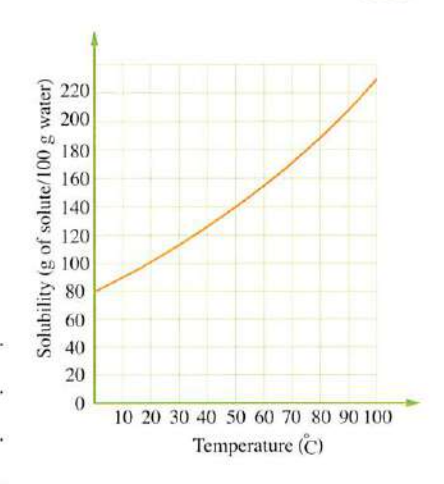
12 **Arrange the following acids ascendingly according to the number of the types of their salts :**

- Phosphoric acid.
- Acetic acid.
- Oxalic acid.

....

13 **The opposite graph** shows the solubility curve of sodium chlorate $NaClO_3$

Calculate the mass of this salt required to be added to its saturated solution at 0°C to remain saturated at 50°C "knowing that the volume of water used as a solvent is 100 mL and its density is 1 g/mL".



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.... 2 marks

14 The following table shows the three dimensions of 4 different substances :

Substance	Length	Width	Height
W	17×10^{-8} m	83×10^{-4} m	96×10^{-3} m
X	111.2×10^{-11} m	201×10^{-10} m	3332.2×10^{-12} m
Y	21×10^{-10} m	0.18×10^{-5} m	17.9×10^{-9} m
Z	130×10^{-7} m	49×10^{-9} m	68×10^{-6} m

State the letter that refers to the substance which is :

(1) A three-dimensional nanosubstance. (..................)

(2) A carbon nanotube. (..................)

.... 1 mark

15 Calculate the mass of 7.1 L of ammonia gas (at STP). [N = 14 , H = 1]

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.... 2 marks

16 Molar concentration of a solution depends on the temperature unlike its molal concentration. Explain this statement.

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.... 1 mark

17 Why are the paints of walls classified as colloids not solutions ?

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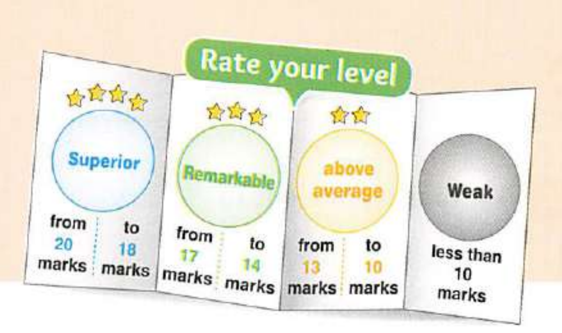
.... 1 mark

Open Book

Exam model 3

Answered



Choose the correct answer for the questions :

1 Which of the solutions shown in the opposite table has the highest pH ?

Solution	A	B	C	D
H^+ concentration (mol/L)	0.1	0.01	0.001	0.0001

(a) A (b) B
(c) C (d) D

2 Which of the following choices describes the aqueous solution of KNO_3 salt ?

(a) Neutral. (b) Strong alkaline.
(c) Weak alkaline. (d) Weak acidic.

3 Which of the following conditions make the dissolving process of 50 g of sugar in 100 g of water the fastest ?

Choices	Form of the sugar	Temperature
(a)	Powder	40°C
(b)	Powder	80°C
(c)	Cubes	40°C
(d)	Cubes	80°C

4 1 mol of ethene gas burns according to the equation :

$$\underset{\text{Ethene}}{C_2H_{4(g)}} + \underset{\text{Oxygen}}{3O_{2(g)}} \longrightarrow 2CO_{2(g)} + 2H_2O_{(v)}$$

What is the number of the moles of the gases and the vapours which are found at the end of the reaction of 1 mol of ethene gas with 4 mol of oxygen gas ?

(a) 2 mol (b) 3 mol
(c) 4 mol (d) 5 mol

5 The reaction of a metal with the acids is represented by the ionic equation :

$$M_{(s)} + 2H^+_{(aq)} \longrightarrow M^{2+}_{(aq)} + H_{2(g)}$$

Which of the following metals does not undergo this reaction ?

(a) Iron. (b) Sodium. (c) Magnesium. (d) Lead.

6 **1 mm is equivalent to ....**

(a) 1×10^6 nm
(b) 1×10^{-6} nm
(c) 1×10^{-7} nm
(d) 1×10^7 nm

7 **The following table shows the mass percentages of the elements of a compound :**

Element	Carbon	Hydrogen	Oxygen
Percentage	26.7%	2.2%	71.1%

What is the empirical formula of this compound ? [C = 12 , H = 1 , O = 16]

(a) CHO_2
(b) $C_2H_2O_4$
(c) CHO
(d) $C_2H_2O_2$

8 **After stirring a sample of copper (II) sulphate in water, ...**

(a) a solution is formed.
(b) a suspension is formed.
(c) a colloid is formed.
(d) a heterogeneous mixture is formed.

9 **Which of the following substances react with water forming bases each contains two hydroxide ions ?**

(a) SO_2 , CO_2 and NO_2
(b) Li , Na and K
(c) Mg , Ca and Ba
(d) O , S and Se

10 **Choose two correct answers :**

Two samples of oxygen and nitrogen gases have the same volume at the same conditions of pressure and temperature.

What is the similarity between these two gases ?

(a) The number of the molecules.
(b) The number of the ions.
(c) The number of the atoms.
(d) The molar mass.
(e) The number of the moles.

.... 2 marks

11 **Calculate the molality of** the solution which results from dissolving 115.2 g of glucose in 400 g of ethanol. [C = 12 , O = 16 , H = 1]

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.... 2 marks

12 **Calculate the freezing point of** calcium chloride solution which contains 1 mol of the solute in 1000 g of water.

....

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.... 1 mark

13 **The opposite table shows** the molecular formulas of 3 different compounds (A), (B) and (C).
Illustrate without calculations which of these compounds its empirical formula has the least molar mass.

(A)	C_2H_4O
(B)	C_2H_6O
(C)	$C_3H_8O_2$

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.... 1 mark

14 **Deduce the molecular formula of each of X and Y in the two following equations after balancing them :**

- $Be_2C + H_2O \longrightarrow BeO + X$
- $CaC_2 + H_2O \longrightarrow Ca(OH)_2 + Y$

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.... 1 mark

15 **The opposite figure illustrates the process of estimating the concentration of the solution in the tool (2) which has a definite volume by the indication of the known concentration and volume of the solution in the tool (1) :**

(1) **What** is the difference between the tool (1) and the tool (2) ?

....

....

(2) **What** is the name of the process which is illustrated in this figure ?

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.... 2 marks

16 **What can be concluded** from the opposite figure ?

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.... 1 mark

17 **Determine the acid and the base in the reaction which is represented by the following equation :**

$$C_2H_5-\ddot{\underset{\cdot\cdot}{O}}-C_2H_5 + AlCl_3 \longrightarrow (C_2H_5)_2\ddot{O}-AlCl_3$$

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.... 1 mark

Open Book
Exam model 4

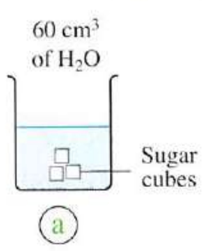
Answered

Choose the correct answer for the questions **:**

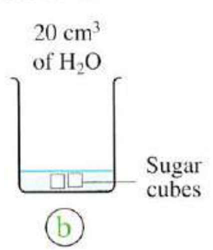
1 **Which of the following equally concentrated solutions has the lowest freezing point ?**

(a) Potassium sulphate. (b) Sodium chloride. (c) Urea. (d) Glucose.

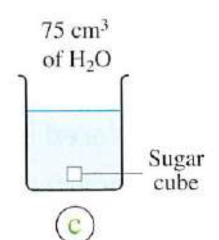
2 **Which of the following sugary solutions is likely to be saturated after the complete dissolution of the sugar cubes in water ?**



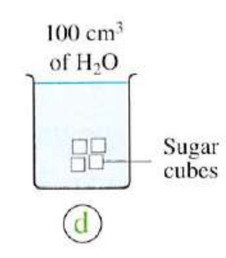
(a)



(b)



(c)



(d)

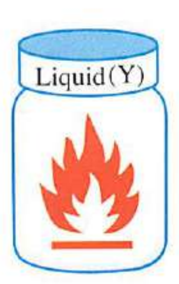
3 **Substance (A) reacts with substance (B) to produce the two substances (X) and (Y) according to the equation :** $2A + 3B \longrightarrow X + 2Y$

What are the amounts of the remaining reactants and those of the products produced from the reaction of 2 mol of (A) with 1 mol of (B) ?

Choices	(A)	(B)	(X)	(Y)
(a)	$\frac{4}{3}$ mol	0	$\frac{1}{3}$ mol	$\frac{2}{3}$ mol
(b)	$\frac{1}{3}$ mol	$\frac{2}{3}$ mol	0	$\frac{4}{3}$ mol
(c)	$\frac{1}{6}$ mol	$\frac{4}{3}$ mol	0	$\frac{1}{3}$ mol
(d)	$\frac{2}{3}$ mol	0	$\frac{4}{3}$ mol	$\frac{1}{6}$ mol

4 **One of the students had noticed the two bottles illustrated in the opposite figures in the school laboratory.**

What is the correct conclusion which was inferred by this student ?



(a) The two liquids (X) and (Y) are acids.

(b) The two liquids (X) and (Y) can not be mixed together.

(c) The liquid (Y) requires heating before use.

(d) The liquid (X) must not be touched without gloves.

5 The empirical formula of a chemical compound is CH_2 and its molar mass is 56 g/mol
What is the molecular formula of this compound ? [C = 12 , H = 1]

(a) CH_2 (b) C_2H_4 (c) C_3H_6 (d) C_4H_8

6 Pb_3O_4 reacts with nitric acid to form lead (II) nitrate, lead (IV) oxide and another product.
Which of the following equations represents this reaction properly ?

(a) $Pb_3O_4 + 4HNO_3 \longrightarrow 2Pb(NO_3)_2 + PbO_2 + 2H_2O$
(b) $Pb_3O_4 + 4HNO_3 \longrightarrow Pb(NO_3)_4 + 2PbO + 2H_2O$
(c) $Pb_3O_4 + 2HNO_3 \longrightarrow 2Pb(NO_3)_2 + PbO_2 + 2H_2O$
(d) $2Pb_3O_4 + 2HNO_3 \longrightarrow 2Pb(NO_3)_2 + 2PbO_2 + H_2$

7 A brown powder had been placed in a test tube, and some distilled water was added to it with shaking, after filtration, a black solid substance remained on the filter paper, and after the vaporization of the water of the formed solution (called the filtrate), orange crystals remained.
It is concluded from the previous observations that ....

(a) the black solid substance is an element.
(b) the brown powder is a compound.
(c) the brown powder is a mixture.
(d) the orange crystals are mixtures.

8 Two drops of each of bromothymol blue and phenolphthalein indicators were added to two samples of two different solutions, pH value of each of them is 2
Which of the following represents the colour formed with each indicator ?

Choices	Bromothymol blue	Phenolphthalein
(a)	Blue	Pink
(b)	Blue	Colourless
(c)	Yellow	Pink
(d)	Yellow	Colourless

9 The solution with the lowest pH value is produced from mixing ....

(a) H_2O with NH_4OH (b) HNO_2 with KOH
(c) HCl with Na_2CO_3 (d) HNO_3 with NaOH

10 **Choose two correct answers :**

All the following about nickel (II) nitrate salt are correct, except that ....

(a) it is an ionic compound.

(b) it dissolves in water.

(c) it reacts with nitric acid.

(d) the boiling point of its aqueous solution is higher than 100°C

(e) the freezing point of its aqueous solution is higher than 0°C

.... / 2 marks

11 **Calculate the molar mass of** bucky ball. [C = 12]

.... / 1 mark

12 **Deduce the molecular formula of** the hydrocarbon in which the mass percentage of carbon is 82.7% and that of hydrogen is 17.3% [C = 12 , H = 1]

.... / 1 mark

13 **The following equation represents the concepts of acid and base :**

$$NH^{+}_{4(aq)} + PO^{3-}_{4(aq)} \rightleftharpoons \ddot{N}H_{3(aq)} + HPO^{2-}_{4(aq)}$$

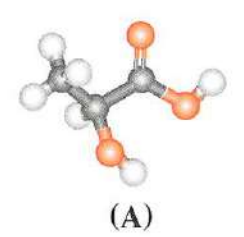
In the light of your studying for the three theories defining acids and bases.

Determine the name(s) of theory(ies)

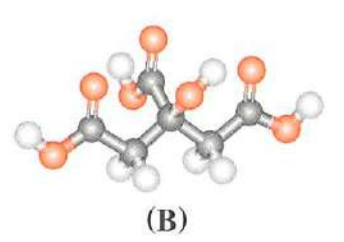
which explain(s) the acid and the base in this equation.

.... / 1 mark

14 **The following figures represent the structural configurations of two acids (A) and (B), one of them is lactic acid and the other is citric acid "in no particular order" :**



(A)



(B)

(1) **Which of** the two figures (A) and (B) represents lactic acid ? **Give reason** for this choice.

....

(2) **What is** the number of basicity of lactic acid ? **What** is its molecular formula ?

....

.... 2 marks

15 **Calculate the number of the molecules of** lithium oxide which are produced from the thermal decomposition of 37 g of lithium carbonate according to the equation :

$$Li_2CO_{3(s)} \xrightarrow{\Delta} Li_2O_{(s)} + CO_{2(g)}$$

[Li = 7 , C = 12 , O = 16]

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.... 2 marks

16 **Calculate the mass percentage of** carbon in methane CH_4 [C = 12 , H = 1]

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.... 1 mark

17 When a little amount of a laundry detergent is added to a trough containing a mixture of hydrochloric acid and magnesium strips, water bubbles are formed with the produced hydrogen gas inside it.

Do these bubbles form a solution or a colloid ? Explain.

....

.... 1 mark

Open Book

Exam model 5

Answered

Choose the correct answer for the questions :

1 **All the following are correct regarding the importance of measurement, except** ....

Choices	Importance	Example
(a)	Monitoring	Determination of insulin dose for a diabetic patient.
(b)	Health care	Monitoring glucose in the blood of a diabetic patient.
(c)	Testing	The composition of a fertilizer.
(d)	Management	Adding an acidic substance to a highly basic soil.

2 **What is the number of molecules of oxygen in 466.6 mL sample (at STP) ?**

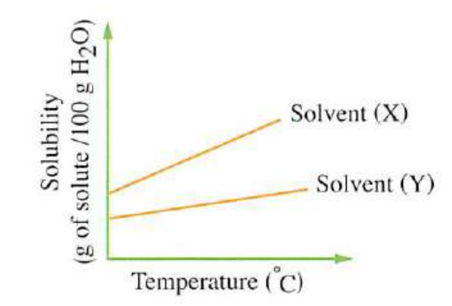
(a) 1.25×10^{22} molecules.
(b) 1.34×10^{22} molecules.
(c) 3×10^{22} molecules.
(d) 3×10^{26} molecules.

3 **1 mol of ethanol C_2H_6O is oxidized by potassium permanganate solution which is acidified with sulphuric acid, forming ethanoic acid $C_2H_4O_2$, the percentage of the actual yield is 60%**

What is the mass of ethanoic acid which can be actually collected from the oxidation of 2.3 g of ethanol ? [C = 12 , H = 1 , O = 16]

(a) 1.32 g
(b) 1.38 g
(c) 1.8 g
(d) 3 g

4 **The opposite graphical figure shows the effect of changing the temperature on the solubility of the solute (S) in two different solvents (X) and (Y), it is clear from this figure that the solubility of the solute (S)** ....



(a) in the two solvents (X) and (Y) is the same.
(b) in the solvent (X) is generally higher than in the solvent (Y).
(c) in the solvent (Y) is generally higher than in the solvent (X).
(d) in the solvent (X) is not affected by raising the temperature.

5 **On dissolving 7.1 g of Na_2SO_4 (its molar mass = 142 g/mol) in water, 0.5 L of ....**

(a) 2.5×10^{-2} M solution is produced.

(b) 1×10^{-1} M solution is produced.

(c) 1×10 M solution is produced.

(d) 1×10^{2} M solution is produced.

6 **Which of the following aqueous solutions of the nonvolatile substance (X) has the highest boiling point ? A solution that contains ....**

(a) 1 mol of (X) in 2 kg of water.

(b) 2 mol of (X) in 1 kg of water.

(c) 1.5 mol of (X) in 1.5 kg of water.

(d) 0.5 mol of (X) in 1 kg of water.

7 **The opposite figure shows a whipped cream in which ....**

(a) a liquid is dispersed in a liquid.

(b) a gas is dispersed in a liquid.

(c) a solid is dispersed in a liquid.

(d) a liquid is dispersed in a solid.

8 **In the reaction which is represented by the following equation :**

$$H_2PO_4^- + H_2O \rightleftharpoons H_3PO_4 + OH^-$$

The two Brönsted–Lowry acids in both reaction directions are ....

(a) H_2O and OH^-

(b) $H_2PO_4^-$ and OH^-

(c) H_2O and H_3PO_4

(d) $H_2PO_4^-$ and H_3PO_4

9 **Ammonia NH_3 is a weak base which ionizes in water, according to the equation :**

$$NH_{3(g)} + H_2O_{(l)} \rightleftharpoons NH^+_{4(aq)} + OH^-_{(aq)}$$

What is (are) the substance(s) which exist(s) in the aqueous solution of ammonia ?

(a) OH^- only.

(b) NH_3 only.

(c) NH_4^+ and OH^- only.

(d) NH_3 , H_2O , NH_4^+ and OH^-

10 **Choose two correct answers :**

Three compounds (A), (B) and (C) : [C = 12 , H = 1 , O = 16]

(A) : CH_3CH_2COOH (B) : CH_3COOCH_3 (C) : $HCOOC_2H_5$

These compounds are similar in all the following, except ....

(a) the mass percentage of carbon and hydrogen in them.

(b) the molar mass.

(c) the number of the elements atoms.

(d) that they are all organic acids.

(e) that they react with Na_2CO_3 forming bubbles.

.... 2 marks

11 **Illustrate** how to protect iron from rusting by using the nanotechnology.

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.... 1 mark

12 The opposite graphical figure illustrates the percentages of the electrical conductivity of 4 different solutions having the same concentration, which are (in no particular order) :

- Fructose.
- Potassium bromide.
- Formic acid.
- Potassium carbonate.

Choose for each solution the letter which refers to it in the figure.

(A) : ....

(B) : ....

(C) : ....

(D) : ....

.... 1 mark

13 When a cube of sugar was added to an aqueous solution of the same sugar, it was observed that it precipitated in the bottom of the container and did not dissolve (apparently).

What is the scientific explanation of this observation ?

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.... 1 mark

14 **Calculate the number of moles of** chloride ions in an aqueous solution that contains 811.75 g of iron (III) chloride salt. [Fe = 55.85 , Cl = 35.5]

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.... 2 marks

15 **The opposite graph represents the masses of iron (III) oxide produced from the combination of iron with oxygen gas under suitable conditions for the reaction :**

(1) **Write** the balanced symbolic chemical equation which represents this reaction.

....

(2) **What is the substance** which remains after the end of this reaction ? **Explain.**

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.... 2 marks

16 **Calculate the number of moles of** the atoms of the elements found in 44.8 L of ammonia gas (at STP).

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.... 1 mark

17 **Write the balanced symbolic equation which represents** the reaction of an acid with a base to form a salt formed of Ca^{2+} cations and NO_3^- anions.

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.... 1 mark

Open Book Exam model 6

Answered

Choose the correct answer for the questions :

1. Each million parts of a river water contains 3 parts of a toxic substance. What is the mass of this substance in 1 kg of the water of this river ?

   (a) 3 g (b) 0.3 g
   (c) 0.03 g (d) 0.003 g

2. What is the mass percentage of hydrogen in chlorous acid $HClO_2$? [H = 1 , Cl = 35.5 , O = 16]

   (a) 1.92% (b) 25%
   (c) 23.4% (d) 1.46%

3. What is the number of nitrogen atoms in 240 g of ammonium nitrate ? [N = 14 , H = 1 , O = 16]

   (a) 2×10^{23} atoms. (b) 6.02×10^{23} atoms.
   (c) 1.81×10^{24} atoms. (d) 36.12×10^{23} atoms.

4. What is the total number of moles of H^+ found in 2.5 L of phosphoric acid whose concentration is 0.7 M ?

   (a) 0.233 mol (b) 2.1 mol
   (c) 5.25 mol (d) 3 mol

5. All the following aqueous solutions almost have the same boiling point, <u>except</u> ....

   (a) 10 mL of 0.1 M NaCl solution.
   (b) 20 mL of 0.05 M NaCl solution.
   (c) 20 mL of 0.07 M $MgCl_2$ solution.
   (d) 13.33 mL of 0.07 M $MgCl_2$ solution.

6. Which of the following colloids are formed from the dispersion of a liquid in a solid ?

   (a) Hair gel, cheese and butter.
   (b) Milk, hair gel and blood.
   (c) Aerosol, hair gel and mayonnaise.
   (d) Mayonnaise, hair gel and cheese.

7 **Each of the following acids when dissolves in water, it can yield more than one proton, except ....**

(a) oxalic acid.

(b) sulphuric acid.

(c) carbonic acid.

(d) acetic acid.

8 **35.5 mL of an aqueous solution contain 22.5 g of sucrose (its molar mass = 342 g/mol). What is the molarity of this solution ?**

(a) 0.0657 M

(b) 1.85×10^{-3} M

(c) 1.85 M

(d) 0.104 M

9 **10 g of hydrogen gas react with excess oxygen gas according to the equation :**

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(v)}$$

What is the reacted volume of oxygen gas (at STP) and the mass of the produced water vapour from this reaction ? [H = 1 , O = 16]

Choices	Reacted volume of O_2	Mass of H_2O
(a)	2.5 L	5 g
(b)	5 L	5 g
(c)	56 L	90 g
(d)	80 L	120 g

10 **Choose two correct answers :**

What happens when a small crystal of the solute substance is placed in its coloured supersaturated solution in a glass beaker ?

(a) The crystal dissolves in the solution.

(b) The solution becomes saturated.

(c) The mass of the beaker increases.

(d) The solution becomes colourless.

(e) The mass of the crystal increases by time.

.... 2 marks

11 Carbon exists in the form of graphite and diamond.

Mention three other forms in which carbon can exist.

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.... 1 mark

12 **Calculate the molar mass** of calcium phosphate compound. [Ca = 40 , P = 31 , O = 16]

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.... 1 mark

13 **Complete the following equation, then write the ionic equation which represents it :**

$$Fe(NO_3)_{2(aq)} + (NH_4)_2CO_{3(aq)} \longrightarrow \ldots\ldots + \ldots\ldots$$

....

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.... 2 marks

14 **What is the type of the aqueous solution** of sodium nitrate salt (acidic, basic or neutral) ? **Explain.**

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.... 1 mark

15 In this reaction : $NH_{3(g)} + H_2O_{(l)} \rightleftharpoons NH^+_{4(aq)} + OH^-_{(aq)}$

What does each of the following represent in the light of Lewis concept of acids and bases :

(1) Ammonia gas.

....

(2) Water.

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.... 1 mark

16 Sulphuric acid is added to barium hydroxide till the completion of the reaction between them.

Write the balanced symbolic equation which represents this reaction, with mentioning the physical state of barium hydroxide only in this reaction, then explain which is larger in number, the ions which are present in the beginning of the reaction **or** the ions which are present at the end of the reaction ?

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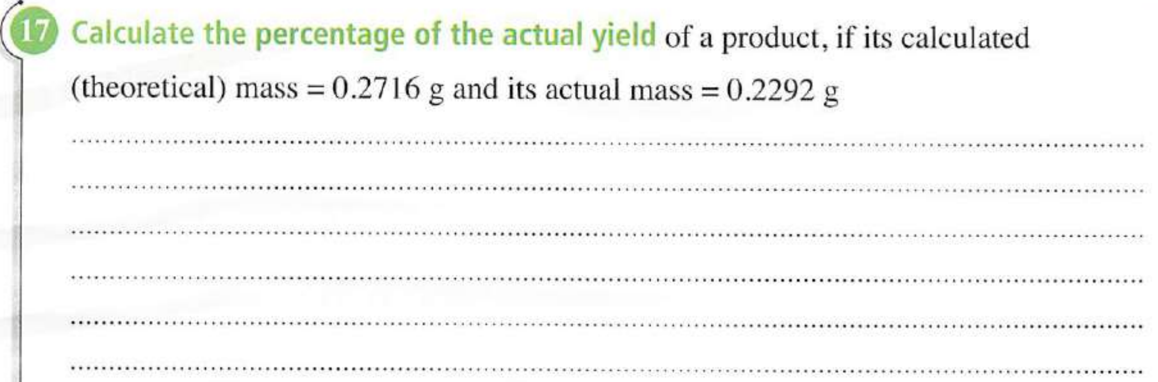
.... 2 marks



17 **Calculate the percentage of the actual yield** of a product, if its calculated (theoretical) mass = 0.2716 g and its actual mass = 0.2292 g

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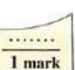


Open Book Exam model 7

Answered

Choose the correct answer for the questions 1 : 9 .... 9 marks

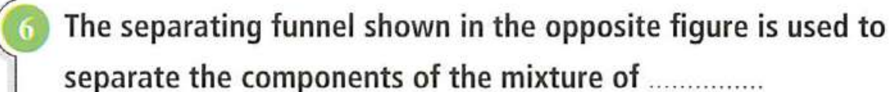
1. **Which of the following expresses the quantitative measurement ?**
   - (a) The burette is longer than the pipette.
   - (b) HCl is stronger than HCN
   - (c) Water is a colourless liquid.
   - (d) The boiling point of ethyl alcohol is 78.37°C

2. **What is the number of moles of hydrogen sulphide in 49.7 g sample of it ?** [S = 32 , H = 1]
   - (a) 0.686 mol
   - (b) 1.46 mol
   - (c) 83.8 mol
   - (d) 24.7 mol

3. **Which of the following compounds is a strong acid ?**
   - (a) H_2CO_3
   - (b) KOH
   - (c) $HClO_4$
   - (d) HClO

4. **16.4 g of HF dissolve in water forming a solution whose volume is 2×10^2 mL and its concentration is** .... [H = 1 , F = 19]
   - (a) 0.82 M
   - (b) 0.16 M
   - (c) 0.08 M
   - (d) 4.1 M

5. **What is the type of the compound which dissolves in water and does not dissolve in benzene ?**
   - (a) Polar only.
   - (b) Nonpolar only.
   - (c) Polar or nonpolar.
   - (d) Polar or ionic.



6. **The separating funnel shown in the opposite figure is used to separate the components of the mixture of** ....
   - (a) cobalt (II) chloride in water.
   - (b) aqueous solution of cobalt (II) chloride in kerosene.
   - (c) milk.
   - (d) copper (II) sulphate in water.

7. **Which of the following choices expresses the dimensions of a two-dimensional nanosubstance ?**

Choices	Length	Width	Height
(a)	1.2×10^{-11} m	200×10^{-10} m	320×10^{-12} m
(b)	21×10^{-10} m	0.18×10^{-5} m	17.9×10^{-9} m
(c)	130×10^{-7} m	49×10^{-7} m	68×10^{-6} m
(d)	17×10^{-8} m	83×10^{-4} m	96×10^{-3} m

8 If the formula of antimony oxide is Sb_2O_3 and that of sodium phosphate is Na_3PO_4, so the formula of antimony phosphate is ....

(a) $SbPO_4$ (b) Sb_2PO_4 (c) $Sb_2(PO_4)_3$ (d) Sb_3PO_4

9 20 mL of carbon monoxide gas combust in excess oxygen gas according to the equation :

$$2CO_{(g)} + O_{2(g)} \xrightarrow{\Delta} 2CO_{2(g)}$$

What is the produced volume of carbon dioxide gas (at STP) ?

(a) 20 mL (b) 40 mL (c) 60 mL (d) 80 mL

10 Choose two correct answers :

The opposite table shows the solubilities of 4 salts (at 20°C). All the following solutions are saturated (at 20°C), except ....

The salt	Solubility (g salt / 100 g H_2O)
Copper (II) chloride	73
Sodium chloride	36
Potassium chloride	34
Ammonium chloride	38

(a) 36.5 g of copper (II) chloride in 50 g of distilled water.

(b) 36 g of sodium chloride in 100 g of distilled water.

(c) 17 g of potassium chloride in 50 g of distilled water.

(d) 18 g of ammonium chloride in 50 g of distilled water.

(e) 37 g of copper (II) chloride in 100 g of distilled water.

.... 2 marks

11 A chemical reaction is expressed by the hypothetical balanced equation :

$$aA + bB \longrightarrow cC + dD$$

What is the number of the possible values of the quantity $\frac{c}{d}$? With explanation.

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.... 1 mark

12 The following figures express the steps of preparation of the pure crystals of one of the salts :

Solid residue

(1) (2) (3) (4)

Mention the name of a salt that can be prepared by this method. With explanation.

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...... 1 mark

13 **In the chemical reaction illustrated by the following equation :**

$$CH_3COOH_{(aq)} + NH_{3(g)} \rightleftharpoons CH_3COO^-_{(aq)} + NH^+_{4(aq)}$$

Relate each compound or ion in the previous equation with the appropriate term from the following :

Conjugate base	Acid	Conjugate acid	Base

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...... 1 mark

14 **In the reaction :** $Ca_3(PO_4)_2 + 3H_2SO_4 \longrightarrow 3CaSO_4 + 2H_3PO_4$

129 g of $Ca_3(PO_4)_2$ were added to 4.4 g of H_2SO_4

Illustrate with chemical calculations the limiting reactant of this reaction.

[$Ca_3(PO_4)_2$ = 310 g/mol , H_2SO_4 = 98 g/mol]

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...... 2 marks

15 If you have 1 mL of each of the colourless hydrochloric acid and phenolphthalein indicator.

How can you differentiate between them by one practical experiment ?

* **Experiment :**

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* **Observation :**

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.... 2 marks

16 **Conclude the chemical formula** of rhenium chloride compound, given that the percentage of rhenium Re in it is 63.6% [Re = 186.2 , Cl = 35.5]

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.... 1 mark

17 **What is the value** of 9.49 s in nanosecond unit ?

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.... 1 mark

Open Book

1 **The conjugate base of bicarbonate group is ....**

(a) HCO_3^- (b) CO_2 (c) CO_3^{2-} (d) H_2CO_3

2 **Avogadro's number is ....**

(a) the number of the atoms in one gram of the element.

(b) the number of the molecules in one gram of the compound.

(c) the volume which is occupied by one mole of a gas at standard conditions.

(d) the number of the molecules in the gram molecular mass of the substance.

3 **The volume percentage of nitrogen in atmospheric air is 78%**
What is the number of moles of nitrogen in 1 L of air (at STP) ?

(a) 0.043 mol (b) 0.035 mol

(c) 0.78 mol (d) 0.87 mol

4 **Ammonia gas reacts with oxygen gas according to the unbalanced equation :**

$$NH_{3(g)} + O_{2(g)} \longrightarrow NO_{(g)} + H_2O_{(v)}$$

What is the number of oxygen moles required to react completely with 6.8 g of ammonia gas ? [N = 14 , H = 1]

(a) 0.5 mol (b) 1 mol

(c) 2.5 mol (d) 5 mol

5 **Which of the following acids has the highest pH value ?**

(a) 0.1 M HCl (b) 0.2 m HCl

(c) 0.1 M CH_3COOH (d) 0.15 m HNO_3

6 **By comparing the freezing point of 1 m sodium nitrate solution with that of 1 m calcium nitrate solution, the freezing point of ....**

(a) both solutions are equal as they are equally concentrated.

(b) calcium nitrate solution is lower as it contains the higher number of ions.

(c) sodium nitrate solution is lower as it contains the higher number of ions.

(d) calcium nitrate solution is lower because its molar mass is larger.

7 Which of the following represents the topical antibiotics which are used in the treatment of skin bacterial infections ?

Choices	Gel	Suspension
a	✓	✓
b	✓	✗
c	✗	✓
d	✗	✗

8 Which of the following solutions has the highest ability to conduct electricity ?

a) 0.1 M HCl
b) 1 M LiOH
c) 2 M H_3PO_4
d) 2 M C_2H_5OH

9 If the chemical formula of calcium pyrophosphate is $Ca_2P_2O_7$, so the chemical formula of iron (III) pyrophosphate is ....

a) $Fe_2(P_2O_7)_3$
b) FeP_2O_4
c) $Fe(P_2O_7)_3$
d) $Fe_4(P_2O_7)_3$

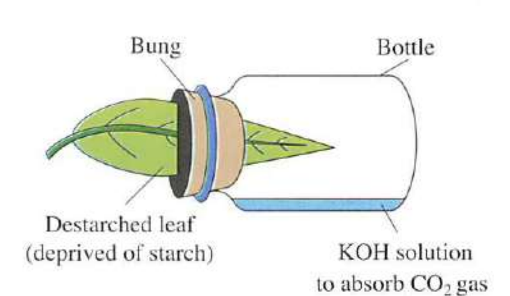
10 Choose two correct answers :

10 nm is equivalent to ....

a) 10^{-8} m
b) 10^{-7} µm
c) 10^{-9} mm
d) 10^{-10} m
e) 10^{-5} mm

11 The opposite figure represents the apparatus used in the experiment of the detection of the effect of CO_2 gas in photosynthesis.

Suggest the science which is likely to be integrated with chemistry in this experiment.



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12 The two opposite figures show two beakers which contain two different aqueous solutions. **Write the net ionic equation which represents the reaction between them.**

NH_4^+ I^-

Ag^+ NO_3^-

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.... 1 mark

13 **Calculate the mass** of potassium in a sample of potassium dichromate $K_2Cr_2O_7$ its mass = 27.8 g

[K = 39 , Cr = 52 , O = 16]

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.... 2 marks

14 **Calculate the number of the moles of** carbon atoms found in a mole of an organic compound its empirical formula is CH_2 and its molar mass equals 42 g/mol

[C = 12 , H = 1]

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.... 1 mark

(15) **Calculate the molar concentration** of 250 mL of a solution which contains 3.01×10^{23} molecules of sodium hydroxide.

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.... 2 marks

(16) The opposite figure represents two beakers (A) and (B), they both contain the same volume of two different solutions which have the same molal concentration.

In which beaker does the level of the surface of the solution decrease over time more than the other ? **Explain.**

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.... 1 mark

(17) A litmus paper wet with water is approached to the mouth of a test tube that contains a hot mixture of ammonium chloride and sodium hydroxide solutions.

What is the change that would occur in the colour of the litmus paper ? Explain.

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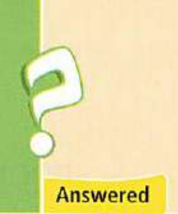
.... 1 mark

Exam model 9



Answered

Choose the correct answer for the questions 1 : 9 .... 9 marks

1 What is the molarity of the solution whose volume is 0.5 L , and contains 0.2 mol of NaOH ?

(a) 0.1 M (b) 0.2 M (c) 2.5 M (d) 0.4 M

2 Which of the following formulas represents an empirical formula ?

(a) N_2O_4 (b) C_3H_6 (c) NH_3 (d) P_4H_{10}

3 In the reaction represented by the equation : $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(v)}$

What is the mass of oxygen gas which reacts completely with 4 g of hydrogen gas ? [O = 16 , H = 1]

(a) 8 g (b) 10 g (c) 16 g (d) 32 g

4 Compared with pure water, 0.1 M sodium chloride solution has ....

(a) higher pH (b) lower boiling point.

(c) higher vapour pressure. (d) lower freezing point.

5 What is the mass of 4 atoms of copper ? [Cu = 63.5]

(a) 254.2 g (b) 2.37×10^{21} g (c) 4.22×10^{22} g (d) 4.22×10^{-22} g

6 A mixture composed of four different substances is added to benzene, after stirring, a substance (X) is precipitated in the bottom of the container, and separated by filtration, on adding the substance (X) to water with stirring then filtration, then heating the solution which is obtained after filtration (called the filtrate) until complete evaporation of water, a white solid residue of substance (Y) remained. What is the ability of the substance (Y) to dissolve in each of benzene and water ?

Choices	Dissolving in benzene	Dissolving in water
(a)	Does not dissolve	Does not dissolve
(b)	Does not dissolve	Dissolves
(c)	Dissolves	Does not dissolve
(d)	Dissolves	Dissolves

7. The following equation is unbalanced :

$$wPCl_5 + xH_2O \longrightarrow yPOCl_3 + zHCl$$

What are the correct coefficients after balancing ?

Choices	w	x	y	z
(a)	1	2	2	4
(b)	2	2	2	2
(c)	2	2	2	1
(d)	1	1	1	2

8. Which of the following represents two reactions, both yield an evolving gas which turns clear limewater milky ?

Choices	The first reaction	The second reaction
(a)	Sodium bicarbonate with hydrochloric acid	Sodium sulphate with nitric acid
(b)	Potassium bicarbonate with sulphuric acid	Calcium carbonate with hydrochloric acid
(c)	Calcium carbonate with sodium hydroxide	Calcium carbonate with hydrochloric acid
(d)	Magnesium carbonate with nitric acid	Calcium sulphite with hydrochloric acid

9. Sodium hydroxide and ammonium hydroxide are similar in all the following , except that both of them ....

(a) are bases.
(b) dissolve in water yielding OH^- ions.
(c) ionize completely in water.
(d) react with hydrochloric acid.

10. Choose two correct answers :

In the reaction :

$$\underset{\text{Compound (1)}}{C_2H_5COOH_{(aq)}} + \underset{\text{Compound (2)}}{CN^-_{(aq)}} \rightleftharpoons \underset{\text{Compound (3)}}{CH_3CH_2COO^-_{(aq)}} + \underset{\text{Compound (4)}}{HCN_{(aq)}}$$

Which of the following statements represents this reaction ?

(a) Compound (1) is H^+ ion donor , while compound (2) is H^+ ion acceptor.
(b) Compound (2) is H^+ ion donor , while compound (1) is H^+ ion acceptor.
(c) Compound (3) is H^+ ion donor, while compound (4) is H^+ ion acceptor.
(d) Compound (4) is H^+ ion donor, while compound (3) is H^+ ion acceptor.
(e) Both the compounds (1) and (3) are H^+ ion acceptors.

.... 2 marks

11 The following table shows the dimensions of four different substances (A), (B), (C), and (D).

Substance	Length	Width	Height
(A)	1.2×10^{-8} m	200×10^{-10} m	322×10^{-10} m
(B)	21×10^{-10} m	0.18×10^{-5} m	17.9×10^{-9} m
(C)	130×10^{-7} m	49×10^{-7} m	68×10^{-6} m
(D)	1.7×10^{-8} m	83×10^{-4} m	96×10^{-3} m

Arrange these substances ascendingly according to their hardness.

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12 A student is asked to prepare a solution of glucose its concentration is 2 m.

What are the required tools ? Show the importance of each of them.

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.... / 1 mark

13 3 g of phosphorus burn in excess of oxygen gas, according to the reaction :

$$P_4 + 3O_2 \longrightarrow P_4O_6$$

So, if the mass of the produced P_4O_6 equals 3.32 g

Calculate the percentage of the actual yield. [P = 31 , O = 16]

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.... 2 marks

14 Among the known ions are : NH_4^+ , Na^+ , $HCOO^-$, NO_3^- , Br^-

What is (are) the formula(s) of the salt(s) which the pH value(s) of its (their) solution(s) is (are) lower than 7 ?

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.... 1 mark

15 A filtration process was carried out for a liquid mixture using the apparatus shown in the opposite figure, after the end of the process, it was found that the mass of the dried filter paper did not change.

can this result indicate the type of this mixture whether a solution, a suspension or a colloid ? **Explain.**

Metal stand
Filter paper
Glass funnel
Beaker

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.... 1 mark

16 An amount of iodine (figure (1)) was added to a heterogeneous mixture of water with another colourless solvent known as cyclohexane, after stirring, the part (X) of the mixture became violet, while a portion of undissolved iodine remained in the part (Y) of the mixture (figure (2)).

IODINE

Figure (1)

(X)

(Y)

Figure (2)

Define the liquid (X), with explanation.

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.... 1 mark

17 Ascorbic acid is known as vitamin (C) , citric acid is found in strawberries and in the berries.

State two other plant sources rich in citric acid and vitamin (C).

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.... 1 mark

Open Book
Exam model 10

Answered

Choose the correct answer for the questions 1 : 9 .... 9 marks

1 In bucky ball, what is the number of carbon atoms that each carbon atom is attached to ?

(a) 1 (b) 2 (c) 3 (d) 4

2 Container (A), its volume is 0.65 L, contains 3.35 mol of H_2 gas, and container (B) whose volume is 1.165 L contains (x) mol of O_2 gas, both gases are exposed to the same conditions of temperature and pressure.

What is the value of (x) ?

(a) 0.226 mol (b) 1.87 mol (c) 6 mol (d) 10.15 mol

3 In which of the following aqueous solutions – all have the same molal concentration – the depression in the freezing point is the most ?

(a) CH_3OH (b) NaF (c) $MnSO_4$ (d) $(NH_4)_2SO_4$

4 $H_2PO_4^-$ acts as an acid in the equation ....

(a) $H_3PO_4 + H_2O \rightleftharpoons H_3O^+ + H_2PO_4^-$

(b) $H_2PO_4^- + H_2O \rightleftharpoons H_3O^+ + HPO_4^{2-}$

(c) $H_2PO_4^- + OH^- \rightleftharpoons H_3PO_4 + O^{2-}$

(d) $HPO_4^{2-} + OH^- \rightleftharpoons H_2PO_4^- + O^{2-}$

5 All the following are colloids, except ....

(a) air in whipped egg white. (b) air in cotton candy.

(c) ground maize powder in water. (d) oxygen in atmospheric air.

6 Molal solution contains 1 mol of the solute in .... (knowing that pure water density = 1 kg/L)

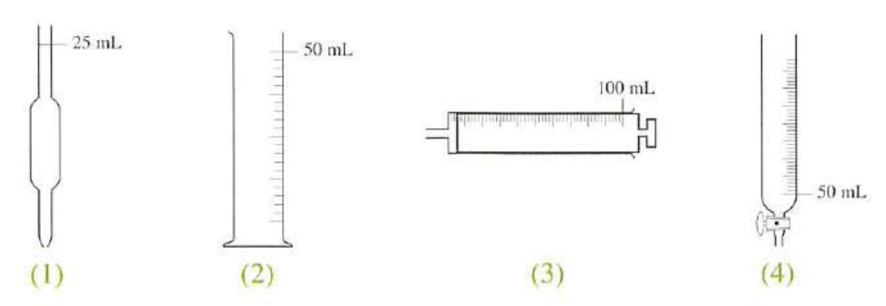
(a) 1000 L of the solvent.

(b) 1000 g of the solution.

(c) 1 L of water.

(d) 22.4 L of the solution.

7 **Here are four different measuring tools :**



Which of the following represents the proper use for one of them ?

Choices	Measuring tool	Used in
a	(1)	Transferring 20 mL of an alkali to carry out a titration.
b	(2)	Collecting 75 mL of the gas produced from a thermal decomposition reaction.
c	(3)	Adding 1 mL of an acid to calcium carbonate.
d	(4)	Adding 15.6 mL of an acid to carry out a titration.

8 **On dissolving ammonium perchlorate salt NH_4ClO_4 in water, the formed solution is ....**

a) acidic. b) neutral.

c) basic. d) amphoteric.

9 **Nitric acid is a strong acid, because ....**

a) it dissolves in water and H^+ concentration in the solution equals OH^- concentration.

b) it does not ionize in water on dissolving in it.

c) it ionizes completely in water into H^+, NO_3^- ions.

d) it is neutralized by a strong base only.

10 **Choose two correct answers :**

Each of the following is a solution, except ....

a) iron filings with sulphur powder.

b) hydrogen chloride gas in water.

c) iodine in benzene.

d) silver in mercury.

e) powdered milk in water.

11 **Calculate the mass of oxygen** in 0.52 g of sodium bicarbonate.

[Na = 23 , H = 1 , C = 12 , O = 16]

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.... 1 mark

12 The opposite figure represents a section in a flexible copper cable, it easily bends with the bends of the plastic pipes inside walls and ceilings.

Is it useful to replace copper which is used in the manufacture of cable wires with any of the following ?

Explain your answer.

(1) Copper nanowires.

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(2) Single-walled carbon nanotubes.

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.... 2 marks

13 The opposite graph shows the solubility curve of four different substances A , B , C and D

Which of these substances its solubility is :

(1) The highest at 10°C

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(2) The lowest at 90°C

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.... 1 mark

14 **Compare between** hydrogen chloride gas **and** glucose **by filling in the spaces in the following table :**

Points of comparison	Hydrogen chloride gas	Glucose
(1) **Solubility in water**	....	....
(2) **Ionization in water**	....	....

.... 2 marks

15 **Rewrite the following word equation as a balanced symbolic equation :**

Magnesium nitrate + Potassium phosphate ⟶ Magnesium phosphate + Potassium nitrate

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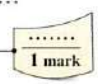
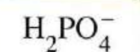


16 **Choose with explanation,** one or more of the following substances that can be present in a test tube which contains phosphoric acid :

PO_4^{3-} | HPO_4^{2-} |  | H_3PO_4

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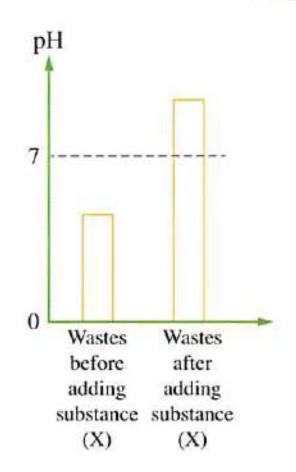
.... 1 mark

17 The opposite graphical figure represents the two pH values of the wastes of a factory before and after adding substance (X).

What is the type of substance (X) ? Explain.



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.... 1 mark

Open Book

Exam model 11

Answered

Choose the correct answer for the questions 1 : 9

1 Nickel-chromium (nichrome) alloy is a ....

ⓐ solution. ⓑ suspension.
ⓒ colloid. ⓓ heterogeneous mixture.

2 When 25 g of KNO_3 are dissolved in 200 g of water with stirring, an aqueous solution of potassium nitrate is formed.
What is the method of calculating the mass percentage of this solution ?

ⓐ $\frac{25}{175} \times 100\%$ ⓑ $\frac{25}{225} \times 100\%$ ⓒ $\frac{25}{200} \times 100\%$ ⓓ $\frac{220}{225} \times 100\%$

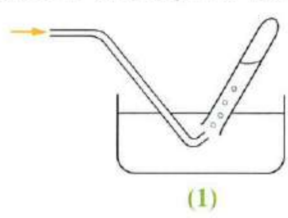
3 All the following examples are correct for the mentioned mixtures, except ....

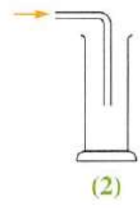
Choices	The mixture	The example
ⓐ	Solid in liquid	Coffee
ⓑ	Liquid in liquid	Antifreezing solution
ⓒ	Gas in liquid	7-up drink
ⓓ	Solid in solid	Copper

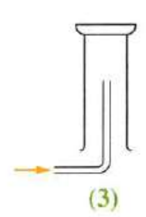
4 A compound with molecular formula X_4O_6, each 10 g of it contain 5.72 g of the element X
What is the atomic mass of the element X ? [O = 16]

ⓐ 32 amu ⓑ 37 amu ⓒ 42 amu ⓓ 98 amu

5 Dilute hydrochloric acid reacts with calcium carbonate forming gas X which is slightly soluble in water, and has higher density than air.


(1)


(2)


(3)

What is the name of the gas X, and what is (are) the proper method(s) to collect this gas ?

ⓐ CO_2 gas / (1) , (2) together. ⓑ H_2 gas / (1) , (3) together.
ⓒ CO_2 gas / (2) only. ⓓ H_2 gas / (3) only.

6 Sulphate salts are prepared by the reaction of dilute sulphuric acid with :

- Active metals.
- Metals oxides.
- Metals carbonates.

What are the substances which can be used in the preparation of copper (II) sulphate salt from dilute sulphuric acid ?

(a) Metal or metal oxide only.

(b) Metal or metal carbonate only.

(c) Metal oxide or metal carbonate only.

(d) Metal, metal oxide or metal carbonate.

7 The opposite table shows the colours and the solubilities of 4 solid substances in water, on adding two of these substances to water with stirring then filtering this mixture, a blue substance remained on the filter paper, and a colourless solution was collected in the flask.

Solid substance	Colour	Solubility in water
(1)	White	Soluble
(2)	White	Insoluble
(3)	Blue	Insoluble
(4)	Blue	Soluble

What are the used substances ?

(a) (1) and (3). (b) (2) and (3). (c) (1) and (4). (d) (2) and (4).

8 Which of the following equations represents the behaviour of a strong Arrhenius acid ?

(a) $CaO_{(s)} + H_2O_{(\ell)} \longrightarrow Ca(OH)_{2(s)}$

(b) $RbOH_{(aq)} \longrightarrow Rb^+_{(aq)} + OH^-_{(aq)}$

(c) $Co(OH)_{2(s)} \xrightarrow{Water} Co^{2+}_{(aq)} + 2OH^-_{(aq)}$

(d) $HClO_{4(aq)} + H_2O_{(\ell)} \longrightarrow ClO^-_{4(aq)} + H_3O^+_{(aq)}$

9 Which of the following represents the tools required to measure the time of dissolution of 2 g of magnesium in 50 mL of dilute hydrochloric acid ?

Choices	Stopwatch	Graduated cylinder	Thermometer	Balance
(a)	✓	✓	✗	✗
(b)	✓	✗	✗	✓
(c)	✓	✓	✗	✓
(d)	✗	✓	✓	✓

10 Choose two correct answers :

Which of the following represents correctly a colourless solution with pH 5 ?

(a) H^+ ions concentration in it is higher than that of OH^- ions.

(b) H^+ ions concentration in it is lower than that of OH^- ions.

(c) It acquires yellow colour with methyl orange.

(d) It remains colourless with phenolphthalein.

(e) H^+ ions concentration in it is higher than that of OH^- ions, and it acquires blue colour with litmus indicator.

.... 2 marks

11 Manufacturing medicines in the form of nanosubstances reduces both their rate of consumption and the side effects.

Explain this statement according to what you have studied.

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.... 1 mark

12 A vacuum vessel contains an amount of a liquid, and is connected to a U-shaped sealed tube containing an amount of mercury at room temperature and under normal pressure (figure (1)), after some time, the rate of evaporation of the liquid became equal to the rate of its condensation, thus the level of mercury in the U-shaped tube changed (as in figure (2)).

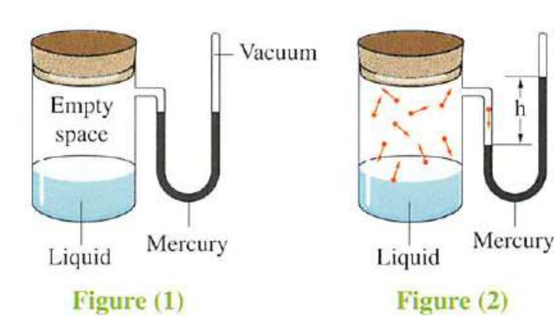

Figure (1) Figure (2)

What does the quantity h represent in figure (2) ?

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.... 1 mark

13 What is the conjugate acid of HPO_4^{2-} ion ?

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.... 1 mark

14 **Deduce the empirical formula** of one of phosphorus oxides, knowing that the mass percentage of phosphorus in it is 43.7% [P = 31 , O = 16]

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.... 2 marks

15 **Balance the following equation :**

$$_\ KMnO_4 + _\ H_2SO_4 \longrightarrow _\ K_2SO_4 + _\ Mn_2O_7 + _\ H_2O$$

.... 1 mark

16 Carbon monoxide gas combusts (burns) in excess of oxygen gas forming carbon dioxide gas, according to the equation : $2CO_{(g)} + O_{2(g)} \xrightarrow{\Delta} 2CO_{2(g)}$

Calculate the volume of carbon dioxide gas (at STP) produced from the combustion of 3.01×10^{23} molecules of carbon monoxide gas.

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.... 2 marks

17 There are two solutions which are equally concentrated,
solution (A) of potassium hydroxide and solution (B) which is NH_3 gas dissolved in water.
Why is there a difference in the electrical conductivity between the two solutions ?

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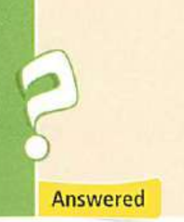
.... 1 mark

Open Book

Exam model 12



Answered

Choose the correct answer for the questions 1 : 9 .... 9 marks

1. $H_2O_{(s)}$ is classified as ....
   - (a) an ionic compound.
   - (b) a covalent compound.
   - (c) a homogeneous mixture.
   - (d) a heterogeneous mixture.

2. Ethanol (its molar mass is 46 g/mol) is prepared from ethylene (its molar mass is 28 g/mol) according to the equation :

$$\underset{\text{Ethylene}}{C_2H_4} + H_2O \longrightarrow \underset{\text{Ethanol}}{C_2H_5OH}$$

So, if you know that 28 g of ethylene yield 43.7 g of ethanol.

What is the percentage of the actual yield ?

   - (a) 64%
   - (b) 84%
   - (c) 95%
   - (d) 156%

3. Which of the following compounds is an Arrhenius acid ?
   - (a) HBr
   - (b) NaOH
   - (c) NaBr
   - (d) NH_3

4. Butane C_4H_{10} burns according to the reaction :

$$2C_4H_{10(g)} + 13O_{2(g)} \longrightarrow 8CO_{2(g)} + 10H_2O_{(v)}$$

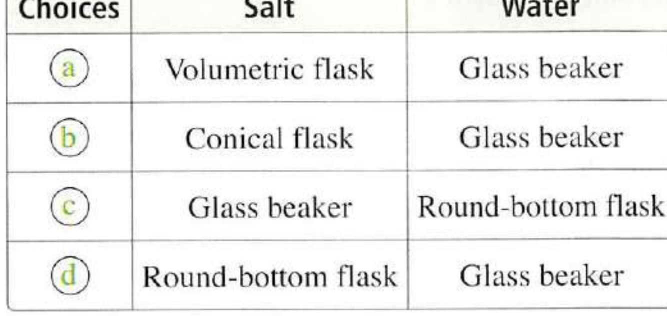
Which of the following represents the correct ratio between oxygen and butane gases as reactants ?

   - (a) $\frac{13 \text{ g } O_2}{2 \text{ g } C_4H_{10}}$
   - (b) $\frac{13 \text{ mol } O_2}{2 \text{ mol } C_4H_{10}}$
   - (c) $\frac{26 \text{ g } O_2}{14 \text{ g } C_4H_{10}}$
   - (d) $\frac{26 \text{ mol } O_2}{14 \text{ mol } C_4H_{10}}$

5 What is the compound which dissolves in water forming a solution that has a relative ability to conduct electricity ?

(a) C_2H_5OH (b) $C_6H_{12}O_6$ (c) $C_{12}H_{22}O_{11}$ (d) CH_3COOH

6 The apparatus which is illustrated in the opposite figure is used in the simple distillation of table salt solution, where is each of the salt and water collected at the end of the experiment ?

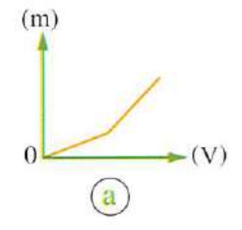


Choices	Salt	Water
(a)	Volumetric flask	Glass beaker
(b)	Conical flask	Glass beaker
(c)	Glass beaker	Round-bottom flask
(d)	Round-bottom flask	Glass beaker

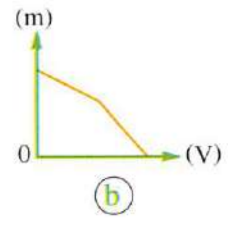
7 On adding excess of potassium iodide KI solution gradually to mercury (II) chloride solution $HgCl_2$, these two reactions occur :

- $HgCl_{2(aq)} + 2KI_{(aq)} \longrightarrow HgI_{2(s)} + 2KCl_{(aq)}$
- $HgI_{2(s)} + 2KI_{(aq)} \longrightarrow K_2HgI_{4(aq)}$

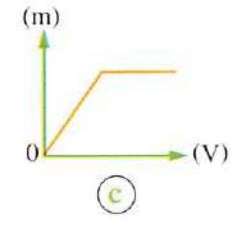
Which of the following graphical figures represents the relation between the mass of the formed precipitate (m) and the added volume of KI solution (V) ?



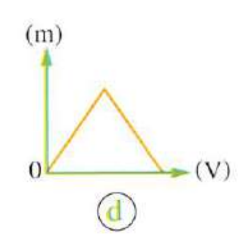
(a)



(b)



(c)



(d)

8 A mole of potassium nitrite is similar to a mole of potassium nitrate in all the following, except ....

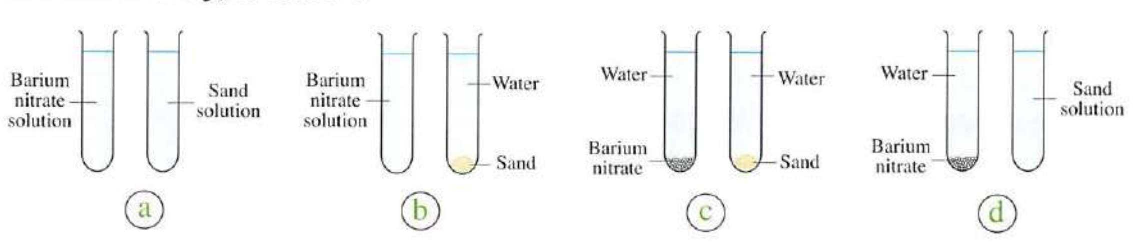
(a) number of moles of O atoms.

(b) number of moles of K atoms.

(c) number of moles of N atoms.

(d) number of moles of the ions in the aqueous solution.

9 **What is expected to happen when each of barium nitrate and sand is stirred, each individually, in water ?**



10 **Choose two correct answers :**

Which of the following represents sulphuric acid ?

(a) 1 mol of sulphuric acid ionizes in water yielding 2 mol of ions.

(b) 1 mol of sulphuric acid reacts with 2 mol of sodium hydroxide.

(c) Sulphuric acid forms only acidic salts.

(d) Sulphuric acid forms two types of salts.

(e) Sulphuric acid reacts with divalent metals only.

.... 2 marks

11 **Calculate the gram mass of** a sample of carbon **[C=12]** which contains quarter of Avogadro's number of atoms.

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.... 1 mark

12 **The opposite graph represents** the solubility curve of potassium nitrate salt KNO_3

Illustrate with the chemical calculations the molality of a saturated solution of KNO_3 (at 40°C). [K = 39 , N = 14 , O = 16]

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.... / 2 marks

13 **Illustrate with explanation** the type of a mixture formed of particles with diameter equals 1.9×10^{-8} m

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.... / 1 mark

14 In the light of the interest of the scientists in reducing the consumption of the aviation fuel, there are attempts being made to replace the copper conductors with plastic conductors known as polyaniline.

What is the substance which is added to polyaniline to render it a better electric conductor than copper ?

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.... / 1 mark

15 Two solutions of glucose, the concentration of the first is 2 M, and that of the second is 1 M **Which of these two solutions has higher boiling point ? Explain.**

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16 A chemical compound its empirical formula is CHO_2 and each 0.5 mol of it contains 1 g of hydrogen.

Deduce the molecular formula of this compound.

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17 Malonic acid is used in synthesis of vitamins B_1 and B_2 :

$HOOC - CH_2 - COOH$
Malonic acid

(1) **Calculate** the mass percentage of oxygen in malonic acid.

[C = 12, H = 1, O = 16]

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(2) **Mention a similarity and a difference** between malonic acid and citric acid.

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.... / 2 marks

Open Book
Exam model 13

Answered

1 **Each of the following is a measurable quantity followed by a measuring unit, except ....**

- (a) pH value of a solution.
- (b) the molality of a solution.
- (c) the nanovolume of solid particles.
- (d) the molar mass of a gas.

2 **All the chemical formulas of the compounds shown in the following table are correct, except ....**

Choices	The compound	The chemical formula
(a)	Aluminum oxide	Al_2O_3
(b)	Calcium nitrite	$Ca(NO_2)_2$
(c)	Iron (II) bromide	Fe_2Br
(d)	Potassium sulphite	K_2SO_3

3 **An element (X) its gram atomic mass is 16 g/mol and its electronic configuration is (2 , 6), another element (Y) its gram atomic mass is 19 g/mol and its electronic configuration is (2 , 7).**
What is the gram molecular mass of the compound which results from the combination of the atoms of the two elements (X) and (Y) ?

- (a) 54 g/mol
- (b) 60 g/mol
- (c) 70 g/mol
- (d) 103 g/mol

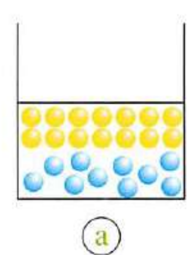
4 **Which of the following represents a pair of conjugate acid and base ?**

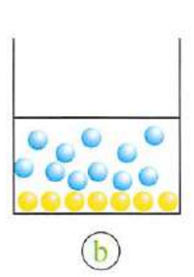
- (a) H_3PO_4 and PO_4^{3-}
- (b) $H_2PO_4^-$ and PO_4^{3-}
- (c) H_3PO_4 and HPO_4^{2-}
- (d) $H_2PO_4^-$ and HPO_4^{2-}

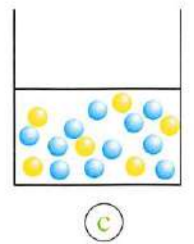
5 In which of the following molecular formulas is the mass percentage of hydrogen the smallest ? [C = 12 , H = 1 , O = 16]

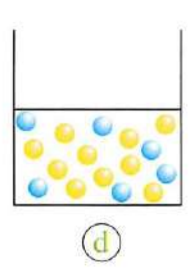
(a) CH_2O_2
(b) C_3H_6O
(c) C_2H_6O
(d) CH_2O

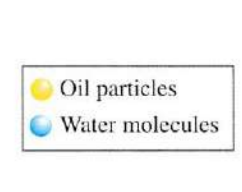
6 Which of the following diagrams expresses a mixture of oil and water ?


(a)


(b)


(c)


(d)



7 All the following factors affect the solubility of the substances, <u>except</u> ....

(a) the temperature.
(b) the speed of the stirring.
(c) the type of the solvent.
(d) the type of the solute.

8 In the reaction :

$$\underset{\text{Compound (A)}}{C_6H_5OH} + 3Cl_2 \longrightarrow \underset{\text{Compound (B)}}{C_6H_2Cl_3OH} + 3HCl$$

When 50 g of the compound (A) react with excess chlorine gas, 97.6 g of the compound (B) are formed.

What is the percentage of the actual yield ? [C = 12 , H = 1 , O = 16 , Cl = 35.5]

(a) 92.9%
(b) 51.2%
(c) 49.4%
(d) 47.6%

9 What is the net ionic equation which represents the formation of barium carbonate salt, which is produced from the reaction of barium chloride solution with sodium carbonate solution ?

(a) $Ba^{2+}_{(aq)} + CO^{2-}_{3(aq)} \longrightarrow BaCO_{3(aq)}$

(b) $Na_2CO_{3(aq)} + BaCl_{2(aq)} \longrightarrow 2Na^{+}_{(aq)} + 2Cl^{-}_{(aq)} + BaCO_{3(s)}$

(c) $Ba^{2+}_{(aq)} + CO^{2-}_{3(aq)} \longrightarrow BaCO_{3(s)}$

(d) $Na_2CO_{3(aq)} + BaCl_{2(aq)} \longrightarrow 2NaCl_{(aq)} + Ba^{2+}_{(s)} + CO^{2-}_{3(s)}$

10 **Choose two correct answers :**

Which of the following is correct ?

(a) The aqueous solution of magnesium oxide its pH is little less than 7

(b) The aqueous solution of sulphur trioxide its pH is much greater than 7

(c) The aqueous solution of ammonium formate its pH is almost 7

(d) Calcium oxide reacts with nitric acid forming salt and water.

(e) Carbon dioxide reacts with hydrochloric acid forming salt.

.... 2 marks

11 **What is the difference between** silver nanoparticles **and** silver particles which can be seen by the naked eye ?

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.... 1 mark

12 **Calculate the molality** of the solution produced from adding 0.25 mol of potassium bromide to 1.25 kg of water.

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.... 1 mark

13 **Show by symbolic equations,** which of them reacts with larger volume of hydrochloric acid, 1 mol of sodium carbonate **or** 1 mol of sodium bicarbonate.

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.... 1 mark

14 **What does happen when each of the following is added to a heterogeneous mixture of water and benzene ? With explanation.**

(1) Oil.

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(2) Potassium hydroxide.

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.... 1 mark

15 **Calculate the mass** of 37.8 L of methane gas (at STP). [C = 12 , H = 1]

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.... 1 mark

16 4.5 g of element (X) react with nitrogen [N=14] forming 23.8 g of X_3N_2

Calculate the number of moles of element (X) which react completely with nitrogen.

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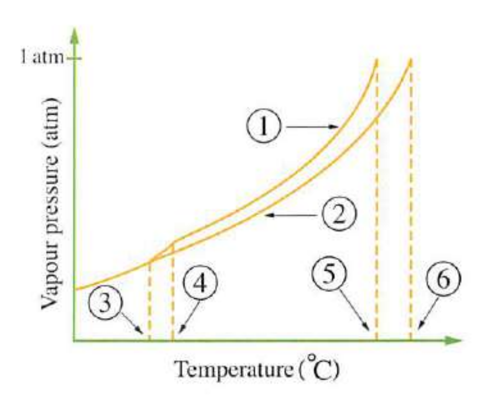
.... 2 marks

17 **The opposite graphical figure represents** the relation between the vapour pressure of each of (pure water and an aqueous solution) and the temperature.

Write beside each term of the following the appropriate number which refers to it (in the graph) :



(1)	......	*Freezing point of solution*	......	*Vapour pressure of solution*	......	*Boiling point of solution*
(2)	......	*Freezing point of pure water*	......	*Vapour pressure of pure water*	......	*Boiling point of pure water*

Which is greater :

The difference between the boiling points of pure water and the solution **or** the difference between the freezing points of pure water and the solution ?

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Open Book
Exam model 14

1 **The screen of the mobile phone is covered with a nanoliquid to form a thin layer on its surface to protect it from scratching and breaking.**

What is the type of the material used in manufacturing this nanoliquid ?

(a) Colloidal substance. (b) One-dimensional nanosubstance.

(c) Suspended substance. (d) Two-dimensional nanosubstance.

2 **Which of the following equations represents the dissolving process of cesium bromide salt in water ?**

(a) $CsBr_{(aq)} \xrightarrow{water} Cs^+_{(aq)} + Br^-_{(aq)}$ (b) $CsBr_{(s)} \xrightarrow{water} Cs^+_{(s)} + Br^-_{(s)}$

(c) $CsBr_{(s)} \xrightarrow{water} Cs^+_{(aq)} + Br^-_{(aq)}$ (d) $CsBr_{(aq)} \xrightarrow{water} Cs^+_{(s)} + Br^-_{(g)}$

3 **The ionic equation which represents the reaction of sodium hydroxide solution with hydrochloric acid does not include each of ....**

(a) Na^+ , Cl^- (b) H^+ , OH^- (c) Na^+ , OH^- (d) H^+ , Cl^-

4 **In the reaction :** $6Li_{(s)} + N_{2(g)} \longrightarrow 2Li_3N_{(s)}$

What is the number of moles of lithium required to react with excess of nitrogen gas to produce 0.6 mol of lithium nitride ?

(a) 0.2 mol (b) 0.3 mol (c) 0.4 mol (d) 1.8 mol

5 **Each of the following is among the properties of lactic acid, except that it ....**

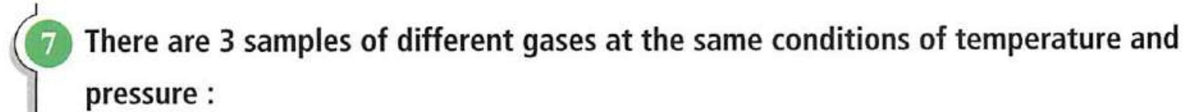
(a) is found in yogurt. (b) is an organic acid.

(c) is a weak acid. (d) reacts with sodium to form salt and water.

6 **These compounds formulas :** KNO_3 , $Pb(NO_3)_2$, $Fe(NO_3)_3$ **indicate that the nitrate group is ....**

(a) monovalent only. (b) divalent only.

(c) trivalent only. (d) mono, di, and trivalent.



7 **There are 3 samples of different gases at the same conditions of temperature and pressure :**

(1) 4 g of argon gas.

(2) 3.2 g of oxygen gas.

(3) 4.4 g of carbon dioxide gas.

What is the correct relation between the volumes of these samples of the gases ?

[Ar = 40 , O = 16 , C = 12]

(a) Volume of sample (1) > Volume of sample (2).

(b) Volume of sample (2) > Volume of sample (3).

(c) Volume of sample (1) = Volume of sample (3).

(d) Volume of sample (3) > Volume of sample (1).

8 **In the opposite table :**

The boiling point of water which contains a little amount of acetone is ....

Substance	Boiling point
Acetone	56°C
Water	100°C

(a) 56°C (b) 78°C (c) 100°C (d) 104°C

9 **Which of the following represents the aqueous solution of each of glucose (its molar mass = 180 g/mol), and the table salt (its molar mass = 58.5 g/mol) ?**

(a) Both are liquid in solid solutions.

(b) Both are electrolytes.

(c) Freezing point of the salt solution is lower than that of glucose solution at equal concentrations.

(d) When each of them contains a mass (X) of the solute in the same volume of water, the concentration of glucose solution is higher than that of the salt solution.

10 Choose two correct answers :

The reaction of acetic acid with sodium hydroxide solution yields a(an) ....

(a) alkaline solution.

(b) acidic solution.

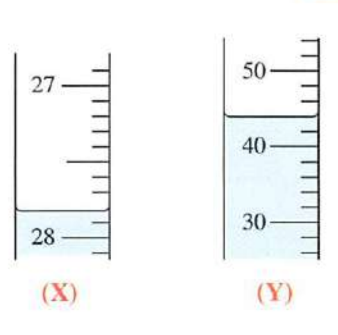
(c) neutral solution.

(d) gaseous solution.

(e) salty solution.

.... 2 marks

11 The opposite figures (X) and (Y) represent two sections in two measuring tools :



- **Tool (X) :** Is used in measuring a definite volume of an acid accurately.
- **Tool (Y) :** Is used in estimating the increase in the volume of water on dipping a piece of iron in it.

What is the name of each tool ?

What is the volume of the measured liquid in each of them ?

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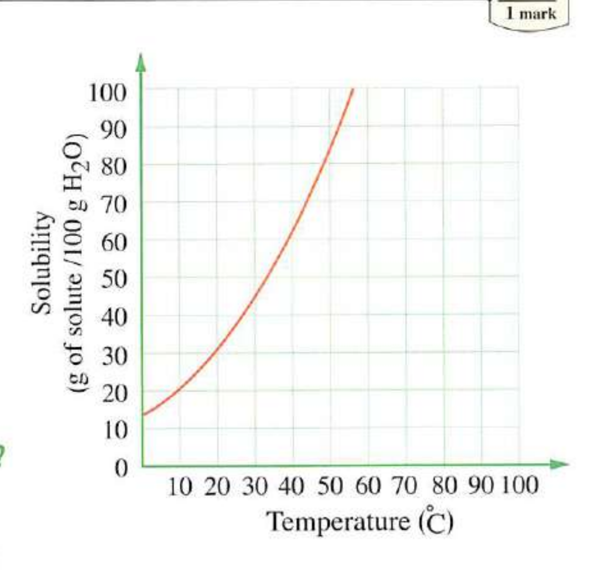
.... / 1 mark

12 According to the opposite figure which represents the solubility curve of potassium nitrate in water, on stirring 75 g of potassium nitrate in 100 g of water at 100°C, no precipitate is formed and when the solution is cooled to 30°C, a precipitate appears.



What is the type of this solution (unsaturated / saturated / supersaturated) ? Explain your answer, and calculate the precipitated mass of potassium nitrate after cooling to 30°C approximately.

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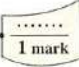

13 **Calculate the mass percentage** of carbon in oxalic acid. [C = 12 , O = 16 , H = 1]

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1 mark

14 **One of the students carried out an experiment to find out the type of the mixture which is composed of substance (X) and water :**

Experiment	Observation
(1) On stirring the mixture well	Substance (X) does not dissolve in water
(2) On leaving the mixture for some minutes after shaking	Substance (X) does not precipitate in water
(3) On pouring the mixture in a funnel containing a filter paper	Substance (X) is not separated from water

Depending on these observations, recognize the type of this mixture, with explanation.

- Is it a solution ?

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- Is it a colloid ?

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- Is it a suspension ?

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2 marks

15 **Illustrate with a symbolic equation only** the definition of an acid in the light of Arrhenius theory.
What is the change that happens to water which contains
some drops of methyl orange indicator by adding the acid to it ?

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.... / 1 mark

16 **Among the well known chemical compounds are :**

- Magnesium hydroxide.
- Magnesium oxide.

(1) **Illustrate with symbolic equations only** a similarity between the two compounds.

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(2) **Why** is magnesium hydroxide described as a base and not an alkali, while magnesium oxide is described as a base and an alkali ?

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.... / 2 marks

17 **Calculate the molar concentration of** a solution of table salt its volume = 1.5 L and contains 26.325 g of sodium chloride whose molar mass = 58.5 g/mol

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.... / 1 mark

Open Book
Exam model 15

1 Which of the following prefixes does not represent its true value ?

(a) Micro = 10^{-6} of the unit. (b) Kilo = 1000 units.

(c) Deci = 10 units. (d) Nano = 10^{-9} of the unit.

2 Substance (A) reacts with substance (B) according to the hypothetical equation :

$$3A + B \longrightarrow C + D$$

What is the limiting reactant of the reaction of 2 mol of (A) with 1 mol of (B) ?

(a) (A) / As its molar mass is the smallest.

(b) (A) / As all its moles are consumed in producing the least number of products moles.

(c) (B) / As the number of its moles is less than the number of moles of (A).

(d) (B) / As 3 molecules of (A) react with 1 molecule of (B).

3 A sample of nitrogen gas its mass is 28 g contains .... [H = 1 , N = 14]

(a) 6.02×10^{23} nitrogen atoms.

(b) 1.204×10^{24} nitrogen molecules.

(c) the same number of nitrogen atoms found in 17 g of ammonia.

(d) the same number of nitrogen atoms found in 34 g of ammonia.

4 Why is glucose soluble in water, while benzene is not, even though they both are organic compounds ?

(a) Due to the difference of their molar masses.

(b) Because glucose is an ionic compound, while benzene is a covalent compound.

(c) Because glucose is a strong electrolyte, while benzene is a weak electrolyte.

(d) Because glucose contains polar (O – H) bonds, while benzene contains C, H only.

5 Which of the following represents the expected boiling and freezing points of an aqueous solution of sodium chloride respectively ?

(a) 98°C , –1.6°C (b) 100°C , 0°C

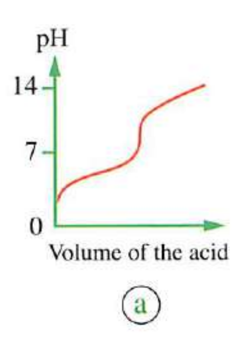
(c) 102°C , –1.6°C (d) 102°C , 0°C

6 **One of the most famous sauces is prepared by whipping egg yolks, and during continuous whipping, oil is added drop by drop, then afterwards drops of vinegar are added.**

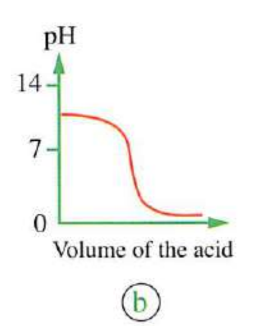
What is the classification of the mixture which composes this sauce ?

(a) Colloid (liquid in liquid).
(b) Colloid (liquid in solid).
(c) Suspension (solid in liquid).
(d) Solution (gas in liquid).

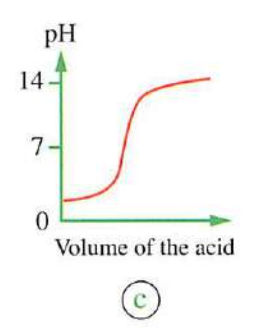
7 **Which of the following curves represents the titration of a weak base with a strong acid ?**



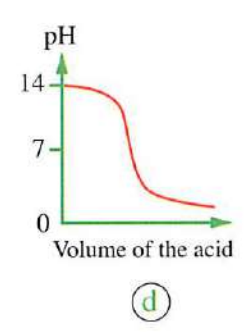
(a)



(b)

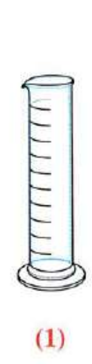


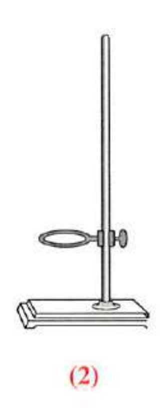
(c)



(d)

8 **Which of the following tools would be used in a titration process ? And what is the missing tool ?**


(1)


(2)

(3)

(4)

Choices	Used tool	Missing tool
(a)	(1) , (2)	Glass beaker
(b)	(2) , (3)	Sensitive balance
(c)	(1) , (4)	Round - bottom flask
(d)	(2) , (4)	Conical flask

9 **Which of the following equations represents correctly the reaction of sodium carbonate solution with sulphuric acid ?**

(a) $Na_2CO_{3(s)} + H_2SO_{4(aq)} \longrightarrow Na_2SO_{4(s)} + H_2O_{(\ell)} + CO_{2(g)}$

(b) $CO^{2-}_{3(aq)} + 2H^+_{(aq)} \longrightarrow H_2O_{(\ell)} + CO_{2(g)}$

(c) $Na^+_{(s)} + CO^{2-}_{3(s)} + H_2SO_{4(aq)} \longrightarrow Na_2SO_{4(aq)} + H_2O_{(\ell)} + CO_{2(g)}$

(d) $CO^{2-}_{3(s)} + 2H^+_{(aq)} \longrightarrow H_2O_{(aq)} + CO_{2(g)}$

10 **Choose two correct answers :**

Which of the following pairs of substances when mixed together, they form a solution its pH is higher than 7 and lower than 13 ?

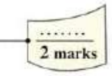
(a) Two equal volumes of hydrochloric acid and sodium hydroxide solution both have the same concentration.

(b) Ammonia solution and water.

(c) Magnesium with excess nitric acid.

(d) Sodium hydroxide and water.

(e) Baking soda and water.



11 "Science fiction is becoming by time and efforts touchable facts".

Clarify the previous statement in the light of astronomers' expectations regarding the use of carbon nanotubes.

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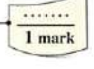

12 **Calculate the molality** of the solution produced from dissolving 2.7 g of CH_3OH in 25 g of H_2O [C = 12 , H = 1 , O = 16]

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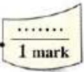

13 Solid scandium element reacts with chlorine to form $ScCl_3$

What is the value of the coefficient of $ScCl_3$ in the balanced chemical equation of the reaction ?

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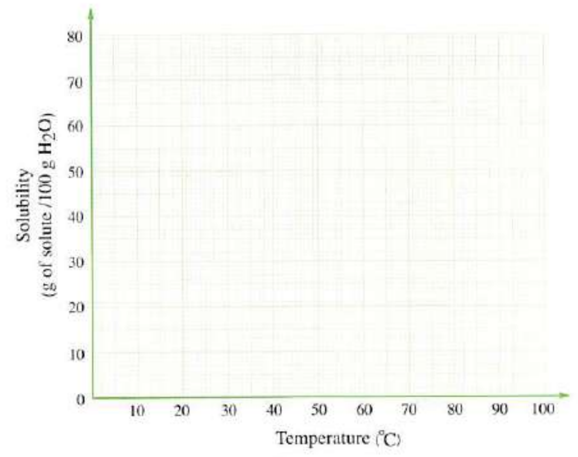
.... 1 mark

14 **The following table shows the solubility of copper (II) sulphate in water at different temperatures :**

Temperature (°C)	0	20	40	60	80	100
Solubility (g of solute/100 g H_2O)	14	20	28	40	56	77

(1) Use the values shown in the previous table to **draw the solubility curve** of copper (II) sulphate.



(2) **What is the maximum mass** of copper (II) sulphate that can be dissolved in 100 g of water at 50°C ?

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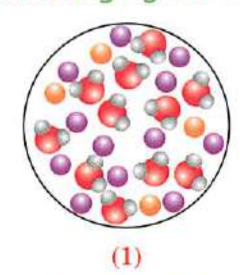
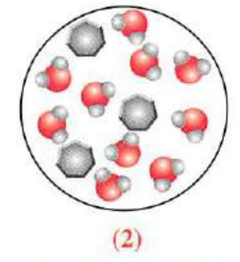
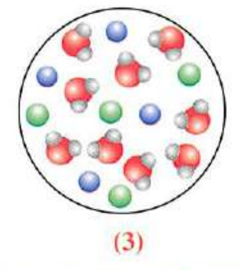
15 **The following figures represent the aqueous solutions of three different compounds :**


(1)


(2)


(3)

Choose from the following compounds what matches each of the previous figures :

(1) Sodium chloride. (...............) **(2)** Potassium phosphate. (...............)

(3) Glucose. (...............)

16 Complete the following equation : $H_2SO_{4(aq)} + H_2O_{(l)} \longrightarrow$ .... $+ H_3O^+_{(aq)}$

Why is water classified in this process as a base ?

....

.... / 1 mark

17 4 balloons are inflated with four different gases at the same conditions of temperature and pressure, their masses are :

- **First balloon :** 4.4 g of CO_2 gas.
- **Second balloon :** 9 g of NO gas.
- **Third balloon :** 9.2 g of NO_2 gas.
- **Fourth balloon :** 11.2 g of CO gas.

Arrange these balloons ascendingly according to their volumes, and explain your answer with chemical calculations. [C = 12 , N = 14 , O = 16]

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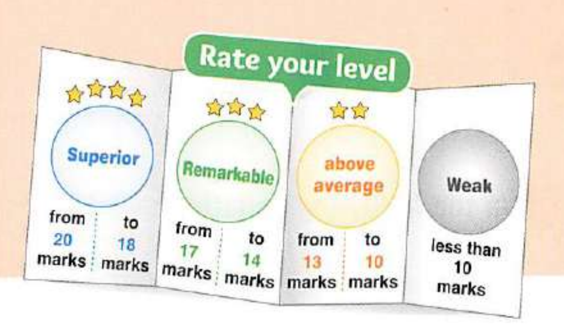
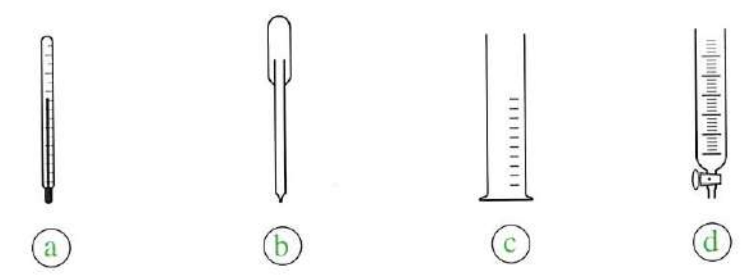
.... / 2 marks

Open Book
Exam model 16

Answered



1 Which of the laboratory tools shown in the following figures can be used to transfer the highly dangerous liquids ?



(a) (b) (c) (d)

2 Which of the following equally concentrated solutions is the best electrical conductor ?

(a) HF (b) HBr (c) HCN (d) H_2SO_3

3 Nitric acid is similar to acetic acid in that they both are ....

(a) organic acids. (b) mineral acids.
(c) strong acids. (d) monobasic acids.

4 What is the empirical formula of the compound that contains 85.6% of carbon and 14.4% of hydrogen ? [C = 12 , H = 1]

(a) CH (b) CH_2 (c) CH_3 (d) CH_4

5 Each of the following is a strong base, <u>except</u> ....

(a) $Ba(OH)_2$ (b) KOH
(c) $Be(OH)_2$ (d) LiOH

6 What is the mass of solute in a solution of ammonium chloride, its volume is 256 mL and its concentration is 0.9 M ? [N = 14 , H = 1 , Cl = 35.5]

(a) 12.3 g (b) 16.3 g (c) 175 g (d) 215 g

7 What is the number of the types of salts that citric acid can form ?

(a) 1 (b) 2 (c) 3 (d) 4

8 In the following equation :

$$C_6H_5NH_{2(aq)} + H_2O_{(l)} \rightleftharpoons C_6H_5NH^+_{3(aq)} + OH^-_{(aq)}$$

Reactants and products can be classified as follows : ....

(a) Acid + Base $\rightleftharpoons$ Acid + Base

(b) Acid + Base $\rightleftharpoons$ Base + Acid

(c) Base + Acid $\rightleftharpoons$ Acid + Base

(d) Base + Acid $\rightleftharpoons$ Base + Acid

9 What is the pair of the equally concentrated solutions which represents a weak base and a strong acid respectively ?

(a) NH_4Cl , HCl

(b) NH_3 , HCl

(c) NH_3 , NaOH

(d) NaOH , HCl

10 Choose two correct answers :

From the opposite solubility curve :

Which of the following substances that are dissolved in 100 g of water (at 40°C) forms a saturated solution ?

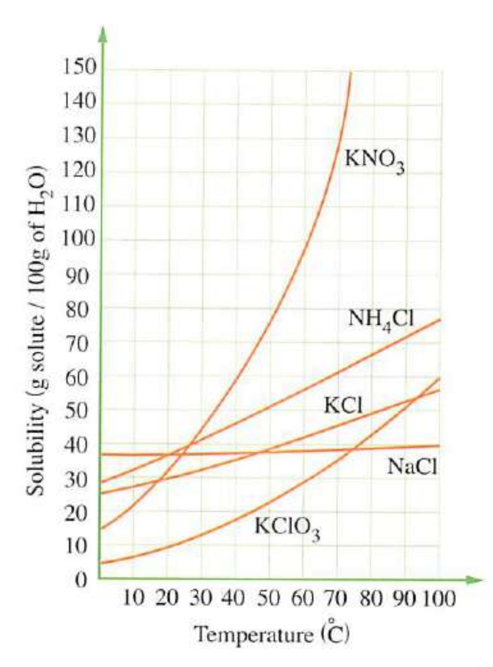
(a) 20 g of $KClO_3$

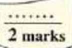
(b) 25 g of NaCl

(c) 30 g of KCl

(d) 40 g of NH_4Cl

(e) 70 g of KNO_3





11 **The opposite figure** shows a nanorobot that Dr. Magdi Yacoub dreams to use in his field to carry out operations without surgery.

Suggest a medical importance for the nanorobot.

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.... 1 mark

12 **Complete the following table with what is suitable from the next substances :**

Gas | Liquid | Solid

Nickel chrome alloy | Atmospheric air | Sea water

Types of solution	Physical state of solute	Physical state of solvent	Example
(1) **Gaseous solution**	....	....	....
(2) **Liquid solution**	....	....	....
(3) **Solid solution**	....	....	....

.... 2 marks

13 **The two opposite figures represent** the structures of phosphorus and sulphur vapours (in no particular order).

If you know that the gram atomic mass of phosphorus is 31 g/mol and that of sulphur is 32 g/mol :

(X) (Y)

(1) **Which figure** represents the structure of phosphorus vapour molecule ?

....

(2) **Calculate the molar mass** of the vapour of each of the two elements.

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.... 1 mark

14 **Calculate the mass of each of the solute and the solvent** in sodium nitrate solution its mass is 500 g and its concentration is 7.5%

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.... / 2 marks

15 In the light of your knowledge about the relation between the vapour pressure and each of the boiling and freezing points of each of pure water and the solution, **replace the numbers shown on the following figures with what suits each of them from the next two terms :**

- Pure water.
- The solution.

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.... / 1 mark

16 **The following ions can form several salts :**

| Na^+ | NH_4^+ | Cl^- | CO_3^{2-} |

Conclude the chemical formula of the salt that dissolves in water forming :

(1) A solution its pH equals 7 (.....................)

(2) A solution its pH is less than 7 (.....................)

(3) A solution its pH is more than 7 (.....................)

.... / 1 mark

17 **Calculate the mass percentage** of hydrogen in magnesium bicarbonate compound, its molar mass is 146 g/mol [H = 1]

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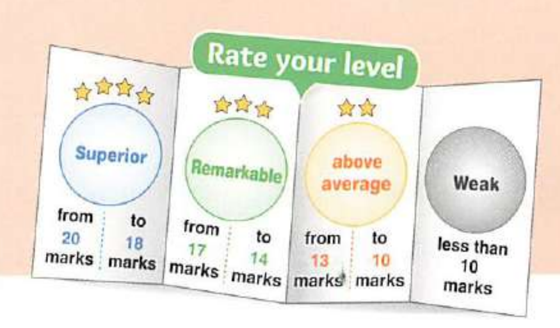
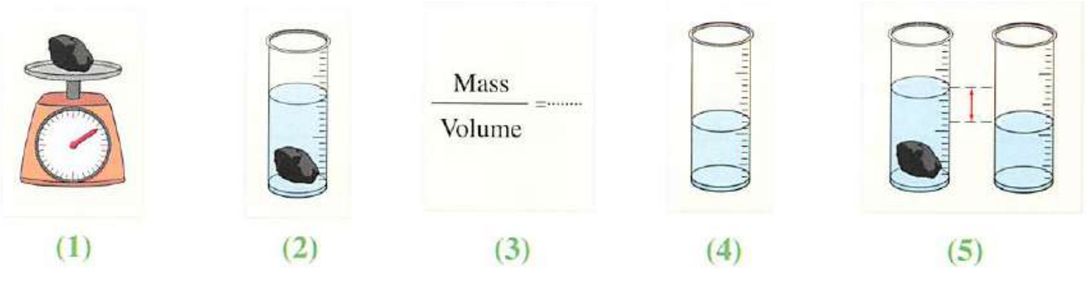
.... / 1 mark

Open Book
Exam model 17

Answered



1. The following cards show the steps of estimating the density of a rock material (in no particular order) :



(1) (2) (3) (4) (5)

What is the correct order of the steps of estimating the density of the rock material ?

(a) (4) → (2) → (1) → (3) → (5).

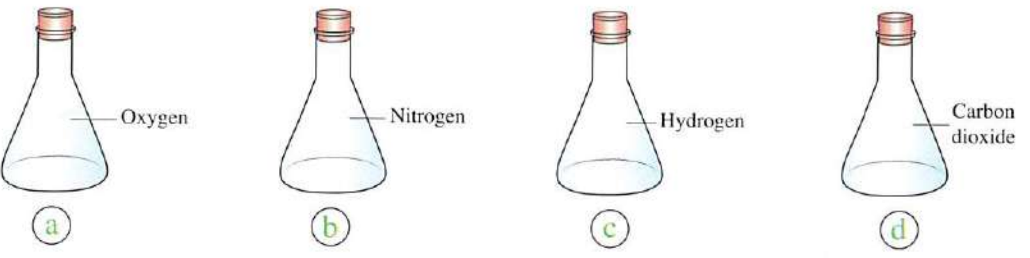
(b) (1) → (4) → (2) → (5) → (3).

(c) (4) → (2) → (1) → (5) → (3).

(d) (1) → (3) → (4) → (2) → (5).

2. These are 4 similar flasks contain four different gases at the same conditions of pressure and temperature.

Which of these flasks has the largest mass ? [O = 16 , N = 14 , H = 1 , C = 12]



3. Which of the following ions can not behave as a base and as an acid in different reactions ?

(a) HPO_4^{2-} (b) SO_3^{2-} (c) $HC_2O_4^-$ (d) HSO_4^-

4. What is the anion that exists in the highest concentration in the solution which is produced from the reaction of 0.1 mol of H_3AsO_4 acid with 0.1 mol of sodium hydroxide ?

(a) $HAsO_4^{2-}$ (b) OH^- (c) $H_2AsO_4^-$ (d) Na^+

5 **Which of the following sodium sulphate crystalline salts loses 56% of its mass after the complete evaporation of all water found in it ?** [Na = 23 , S = 32 , O = 16 , H = 1]

(a) $Na_2SO_4.H_2O$
(b) $Na_2SO_4.2H_2O$
(c) $Na_2SO_4.10H_2O$
(d) $Na_2SO_4.8H_2O$

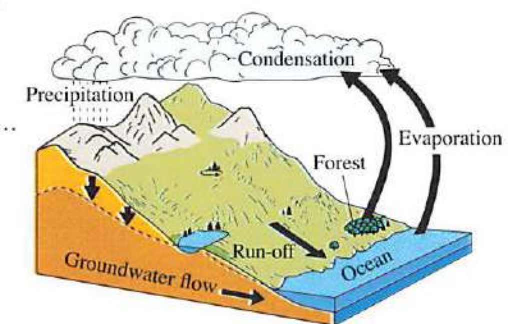
6 **A solution is prepared by dissolving 1.25 mol of an unknown substance in 1000 g of pure water, it is possible to find out whether this solute is an electrolyte or a nonelectrolyte by measuring ....**

(a) pH of the solution.
(b) the boiling point of the solution.
(c) the mass of the solution.
(d) the molal concentration of the solution.

7 **Which of the following ions produces gas bubbles on adding hydrochloric acid to its solid salt ?**

(a) Zn^{2+}
(b) SO_4^{2-}
(c) Cl^-
(d) HCO_3^-

8 **The opposite figure illustrates the natural water cycle, the occurring processes show an obvious integration between sciences, which are ....**



(a) physics, geology and astronomy.
(b) biology, chemistry and geology.
(c) pharmacy, astronomy and chemistry.
(d) agriculture, environment and mathematics.

9 **Ethane gas reacts with oxygen according to the equation :**

$$2C_2H_{6(g)} + 7O_{2(g)} \xrightarrow{\Delta} 4CO_{2(g)} + 6H_2O_{(v)}$$

What is the volume of CO_2 gas (at STP) which is produced when 4 L of ethane gas react with excess of oxygen gas ?

(a) 2 L
(b) 3 L
(c) 4 L
(d) 8 L

10 Choose two correct answers :

Which of the following represents an empirical formula and also a molecular formula at the same time ?

(a) C_3H_4

(b) C_4H_6

(c) $C_6H_{12}O_6$

(d) $C_{12}H_{22}O_{11}$

(e) $C_2H_4O_2$

.... 2 marks

11 Chloroethene C_2H_3Cl reacts with oxygen according to the equation :

$$2C_2H_3Cl_{(g)} + 5O_{2(g)} \longrightarrow 4CO_{2(g)} + 2H_2O_{(v)} + 2HCl_{(g)}$$

Calculate the number of H_2O molecules produced from the reaction of 10 mol of C_2H_3Cl with excess of oxygen gas.

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.... 1 mark

12 **How can the reaction** of a concentrated solution of NaOH with 1 M $(NH_4)_2SO_4$ solution **be indicated ? Write the balanced symbolic equation** including the physical states of the reactants and products.

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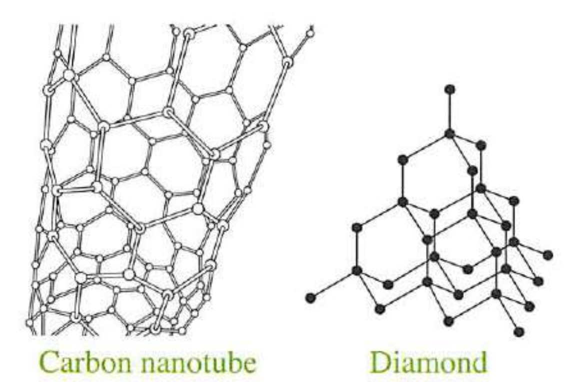
.... 2 marks

13 **The opposite figures show** the molecular structure of diamond and carbon nanotubes :



(1) **Which of them** is better as a heat conductor, diamond **or** carbon nanotubes ?

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(2) **Which is harder,** carbon nanotubes **or** steel ? **Why ?**

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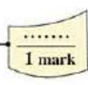
.... 1 mark

14 **According to the reaction shown by the equation :**

$$2SO_{2(g)} + O_{2(g)} \xrightarrow{\Delta} 2SO_{3(g)}$$

What is the limiting reactant of the reaction upon mixing 1.5 mol of O_2 with 2.5 mol of SO_2 ?

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.... 2 marks

15 **Calculate the mass of magnesium oxide** that can be obtained from the reaction of a sample of magnesium its mass is 2.4 g with excess of oxygen gas. [Mg = 24 , O = 16]

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.... 1 mark

16 **Plan a practical experiment** to prepare 3 L of K_3PO_4 solution with 0.2 M concentration. Given that the molar mass of K_3PO_4 compound equals 212 g/mol

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.... 1 mark

17 **Calculate the freezing point of** 1 m ammonium sulphate aqueous solution.

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.... 1 mark

Open Book
Exam model 18

Answered

1 The opposite table shows the classification of some compounds. Which of the following represents the two groups (A) and (B) more accurately ?

(A)	(B)
$HClO_4$	$LiOH$
H_2SO_4	$NaOH$
HI	KOH
HBr	$Ca(OH)_2$
HCl	$Sr(OH)_2$
HNO_3	$Ba(OH)_2$

Choices	(A)	(B)
(a)	Weak acids	Weak bases
(b)	Strong acids	Weak bases
(c)	Strong acids	Strong bases
(d)	Weak acids	Strong bases

2 The chemical compound whose molecular molar mass equals its empirical molar mass is ....

(a) C_4H_6 (b) N_2H_4 (c) K_2O_2 (d) V_2O_5

3 An unknown liquid, its molar mass equals 70 g/mol and its density is 1.2 g/mL if you know that each 2 mL of this liquid give an average of 23 drops.
What is the number of molecules of this liquid in one drop (where N_A is Avogadro's number) ?

(a) $(\frac{1.2}{35}) N_A$ (b) $\frac{1}{1.2}(\frac{1}{35})^2 N_A$ (c) $\frac{1.2}{(35)^2} N_A$ (d) $1.2\, N_A$

4 Cosmology is a branch of astronomy that involves the origin and evolution of the universe.
What are the sciences which combine with cosmology ?

(a) Chemistry, geology and biology.
(b) Mathematics, geology and biology.
(c) Physics, astronomy and mathematics.
(d) Chemistry, physics and mathematics.

5 1.24 g of the element P are found in 2.2 g of .... [P = 31 , S = 32]

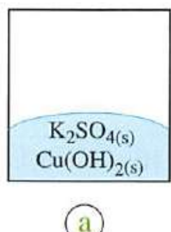
(a) P_4S_3 (b) P_2S_2 (c) PS_2 (d) P_2S_4

6 According to the reaction : $2Al_{(s)} + 6NaOH_{(aq)} \longrightarrow 2Na_3AlO_{3\,(aq)} + 3H_{2(g)}$

What is the volume of the evolved hydrogen gas (at STP) when 27 g of aluminum [Al = 27] react with excess of sodium hydroxide ?

ⓐ 22.4 L ⓑ 44.8 L ⓒ 67.2 L ⓓ 33.6 L

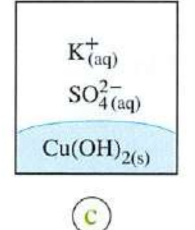
7 What is the figure which represents the heterogeneous mixture of $KOH_{(aq)}$ solution and $CuSO_{4(aq)}$ solution ?



ⓐ

$K^+_{(aq)}$
$SO^{2-}_{4(aq)}$
$Cu^{2+}_{(aq)}$
$OH^-_{(aq)}$

ⓑ

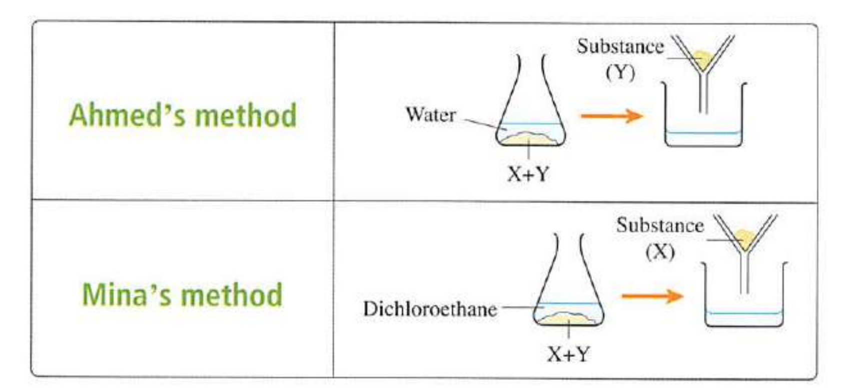


ⓒ

$Cu^{2+}_{(aq)}$
$OH^-_{(aq)}$
$K_2SO_{4(s)}$

ⓓ

8 A mixture composed of an ionic compound (X) and an organic compound (Y), Ahmed and Mina suggested two different methods to separate them.



Which of these methods is correct ?

Choices	Ahmed's method	Mina's method
ⓐ	✓	✓
ⓑ	✓	✗
ⓒ	✗	✓
ⓓ	✗	✗

9 The acidic solution whose concentration is 0.01 M and pH = 2 is probably ....

ⓐ H_2CO_3 ⓑ HNO_3 ⓒ CH_3COOH ⓓ H_3PO_4

10 Choose two correct answers :

The two substances which can be used to change pH value of the soil are ....

(a) calcium chloride.

(b) calcium hydroxide.

(c) sodium nitrate.

(d) potassium sulphate.

(e) ammonium nitrate.

.... 2 marks

11 Balance the following equation :

$$__ H_3PO_3 \longrightarrow __ H_3PO_4 + __ PH_3$$

.... 1 mark

12 Suggest a safe therapy for cancer which can avoid the harms of the chemotherapy and the radiotherapy.

....

....

....

.... 1 mark

13 Calculate the molal concentration of an aqueous solution of glucose (its molar mass is 180 g/mol) and its mass percentage concentration is 10%

....

....

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.... 1 mark

14 **The opposite graph** represents the solubility curve of potassium bromide salt.

Calculate the mass of the saturated aqueous solution of potassium bromide (at 50°C) when the mass of the solute in it equals 120 g

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.... 2 marks

15 **The two opposite figures show two solutions (A) and (B) having the same volume and molality :**

(1) **Suggest** a symbol for each of the two ions (X) and (Y).

....

....

(2) **What is the symbol** of the solution with the higher boiling point ?

....

.... 2 marks

16 An aqueous solution contains a spoonful of sugar and another spoonful of table salt.

Can the salt be separated from the sugar by filtration ? Why ?

....

....

.... 1 mark

17 **The reaction of zinc metal with hydrochloric acid is represented by the following hypothetical equation :**

$$M_{(s)} + 2HX_{(aq)} \longrightarrow MX_{2(aq)} + H_{2(g)}$$

Suggest a hypothetical equation to represent the concept of Arrhenius base in the light of the previous reaction.

....

....

Open Book
Exam model 19

Answered

Choose the correct answer for the questions 1 : 9 .... 9 marks

1 **In the opposite figure :**
What is the approximate value of the reading (X) ?

65 cm — X — 70 cm

(a) 68.2 cm (b) 680 mm (c) 668 mm (d) 67.5 cm

2 **What does happen on mixing two equal volumes of 0.2 M K_2CO_3 solution with 0.2 M Na_3PO_4 solution ?**

(a) No precipitate is formed.
(b) A precipitate of K_3PO_4 is formed.
(c) A precipitate of Na_2CO_3 is formed.
(d) Precipitates of K_3PO_4 and Na_2CO_3 are formed.

3 **The conjugate base of water is ....**

(a) O^{2-} (b) OH^- (c) H_3O^+ (d) H_2O_2

4 **Which of the following is chemically correct ?**

Choices	Concentration of acid	pH	Strength of acid
(a)	0.01 M	2	Strong
(b)	0.01 M	1	Weak
(c)	3 M	5.5	Strong
(d)	3 M	– 0.5	Weak

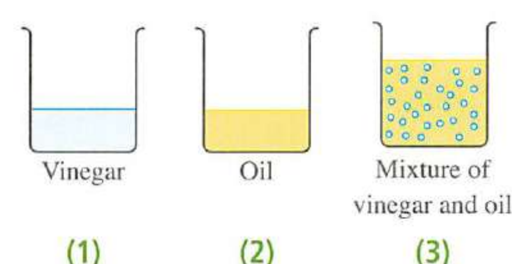
5 **The following solutions are equal in concentration, which of them is alkaline ?**

(a) $MgCl_2$ (b) K_2CO_3
(c) $NaNO_3$ (d) $(NH_4)_2SO_4$

6 **The value which is not followed by a measuring unit is ....**

(a) the molar mass. (b) the nano shell diameter.
(c) the molal concentration. (d) pH

7 On mixing the components of the beakers (1) and (2), the mixture (3) is formed as in the opposite figures.
Which of the following expresses the formed mixture and its components ?



Choices	(1)	(2)	(3)
(a)	The solute	The solvent	A solution
(b)	The dispersed phase	The dispersion medium	A solution
(c)	The solute	The solvent	A colloid
(d)	The dispersed phase	The dispersion medium	A colloid

8 A sample of potassium chlorate $KClO_3$ was heated in an open test tube, so it decomposed according to the equation :

$$2KClO_{3(s)} \xrightarrow{\Delta} 2KCl_{(s)} + 3O_{2(g)}$$

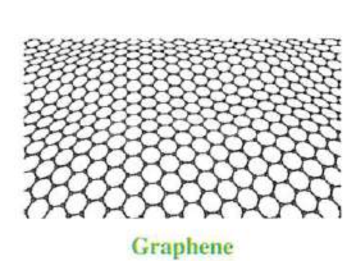
What is the percentage of the lost substance of potassium chlorate at the end of the reaction ? [K = 39 , Cl = 35.5 , O = 16]

(a) 12% (b) 28% (c) 39% (d) 30%

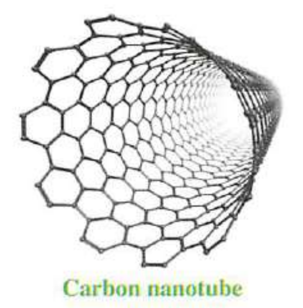
9 The mixture of silt in water is ....
(a) a heterogeneous colloidal mixture.
(b) a homogeneous suspension mixture.
(c) a solution whose contents can not be separated by filtration.
(d) a suspension mixture whose contents can be separated by filtration.

10 Choose two correct answers :
In the reaction : $CaCO_{3(s)} + 2HNO_{3(aq)} \longrightarrow Ca(NO_3)_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$
0.08 mol of nitric acid is added to 0.05 mol of calcium carbonate.
Which of the following is correct after the end of the reaction ?
(a) 0.05 mol of CO_2 is produced.
(b) 0.08 mol of $Ca(NO_3)_2$ is produced.
(c) 0.04 mol of H_2O is produced.
(d) 0.01 mol of $CaCO_3$ remains unreacted.
(e) 0.03 mol of HNO_3 remains unreacted.

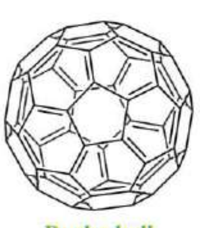
11 **The following figures show** the structure of graphene film which can be converted into single-walled carbon nanotubes and Bucky ball :



Graphene



Carbon nanotube



Bucky ball

(1) Compare between the rings forming each of graphene **and** Bucky ball "**in terms of :** Number of carbon atoms of each ring".

....

....

(2) Mention another difference between carbon nanotube **and** Bucky ball **"other than the geometrical shape of carbon rings".**

....

....

....

12 The mass of one drop of ethyl alcohol (C_2H_5OH = 46 g/mol) is 2.3×10^{-3} g

Calculate the number of the molecules of the alcohol in this one drop.

....

....

....

....

....
1 mark

13 **The opposite graphical figure represents** the vapour pressure curves for two pure liquids (A) and (B), in addition to the solution results from mixing them (C).
If the liquid (A) is more volatile than the liquid (B).
Relate each curve to one of the letters (A) , (B) and (C).

P (atm)
(1)
(2)
(3)
T (°C)

14 **Write the chemical equations that represent the dissolution of each of the following substances :**

(1) $Na_2SO_{4(s)}$ (strong electrolyte).

....

....

(2) $CH_4N_2O_{(s)}$ (nonelectrolyte).

....

....

(3) $HBrO_{(aq)}$ (weak electrolyte).

....

....

.... 1 mark

15 **Calculate the molar mass of the compound produced from** the combination of potassium element with selenium element which lies below oxygen (in the same group) in the modern periodic table. [K = 39 , Se = 79]

....

....

....

.... 1 mark

16 **Calculate the percentage of the practical yield,**

when 5 g of ethanol C_2H_5OH react with excess of potassium permanganate $KMnO_4$ to form 4.24 g of acetic acid CH_3COOH according to the equation :

$$3C_2H_5OH + 4KMnO_4 \longrightarrow 3CH_3COOH + 4MnO_2 + 4KOH + H_2O$$

[C = 12 , H = 1 , O = 16]

....

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.... 2 marks

17 An unknown compound contains 24.2% carbon, 4% hydrogen and the rest is chlorine.

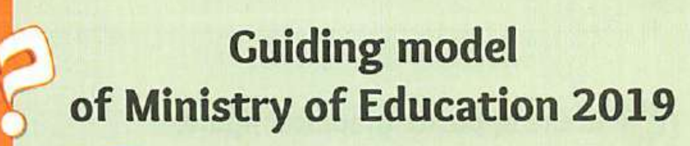
What is the molecular formula of this compound ?

Given that its molar mass is 148.5 g/mol [C = 12 , H = 1 , Cl = 35.5]

....

2 marks

Open Book
Exam model 20



Choose the correct answer for the questions 1 : 6

1 **Which of the following solutions has the highest boiling point ?**

(a) 1 M sodium carbonate.
(b) 2 M sodium carbonate.
(c) 1 M iron (III) chloride.
(d) 2 M iron (III) chloride.

2 **Number of atoms in half a mole of formaldehyde HCHO equals ....**

(a) Avogadro's number.
(b) $\frac{1}{2}$ Avogadro's number.
(c) 2 × Avogadro's number.
(d) $\frac{1}{4}$ Avogadro's number.

3 **On dissolving 55.5 g of calcium chloride $CaCl_2$ in water to form a solution its volume = 0.5 L , the concentration of this solution equals ....** [Ca = 40 , Cl = 35.5]

(a) 1 M
(b) 0.5 M
(c) 2 M
(d) 1.5 M

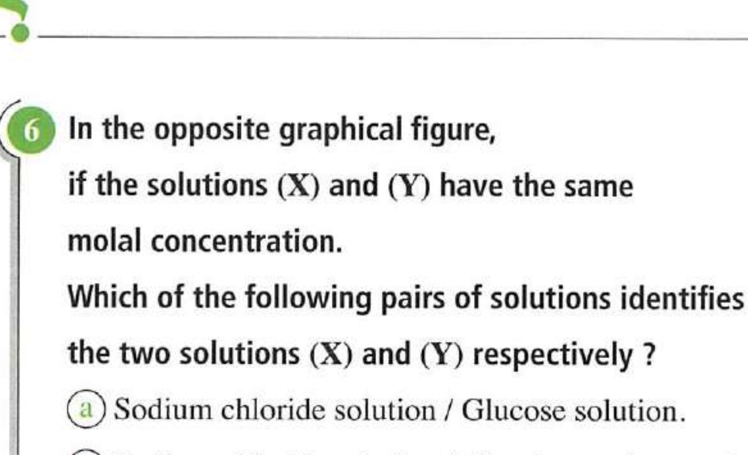
4 **An experiment was carried out to find the molecular formula of an unknown compound which contains three elements (A), (B) and (C), it was found that the mass percentage of the element (A) is 40% and that of the element (B) is 12% What is the molecular formula of this compound, knowing that it is also the empirical formula ?** [A = 40 , B = 12 , C = 16]

(a) ABC_3
(b) A_3BC
(c) AB_3C
(d) A_2B_2C

5 **The opposite graph represents the relation between the solubility of some substances and the temperature. Which of these substances its solubility increases the most by increasing the temperature of the solvent ?**

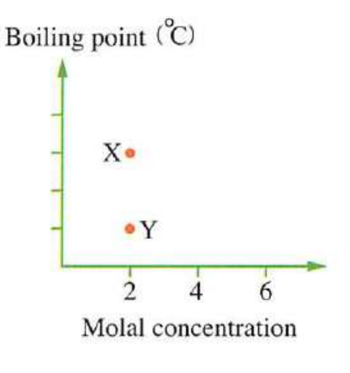
Solubility (g solute /100 g H_2O)
Temperature (°C)
A B C
D

(a) A
(b) B
(c) C
(d) D



6 **In the opposite graphical figure, if the solutions (X) and (Y) have the same molal concentration.**

Which of the following pairs of solutions identifies the two solutions (X) and (Y) respectively ?



(a) Sodium chloride solution / Glucose solution.

(b) Sodium chloride solution / Aluminum nitrate solution.

(c) Potassium carbonate solution / Aluminum nitrate solution.

(d) Potassium carbonate solution / Glucose solution.

7 **From the following radicals :**

CH_3COO^- | SO_4^{2-} | Na^+ | NH_4^+

Deduce the chemical formula of the salt, which dissolves in water forming a solution with pH value higher than 7

....

....

....

....

8 **Arrange the following acids ascendingly according to their number of basicity :**

H_3BO_3 / HCN / H_2SO_3

....

9 **Deduce the conjugate acid and the base according to Brönsted - Lowry theory in the following equation :** $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$

....

....

10 In the opposite graph.

Which of the illustrated compounds (A, B, C, D, or E) represents the ionization of an organic acid in water ? Why ?

....

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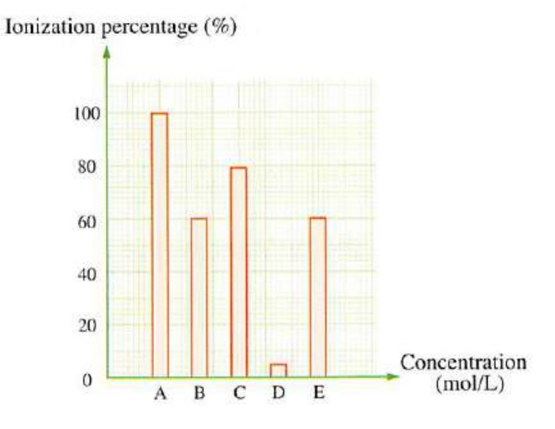

11 **Calculate the number of moles of iron (III) oxide Fe_2O_3** produced from heating 456 g of iron (II) sulphate $FeSO_4$ according to the equation : **[Fe = 56 , S = 32 , O = 16]**

$$2FeSO_4 \xrightarrow{\Delta} Fe_2O_3 + SO_2 + SO_3$$

....

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....

....

12 **The opposite graph represents** the relation between the volume of hydrogen gas which evolves from the reaction of a limited amount of magnesium with excess of hydrochloric acid by time.

Deduce the time of consumption of half the amount of magnesium.

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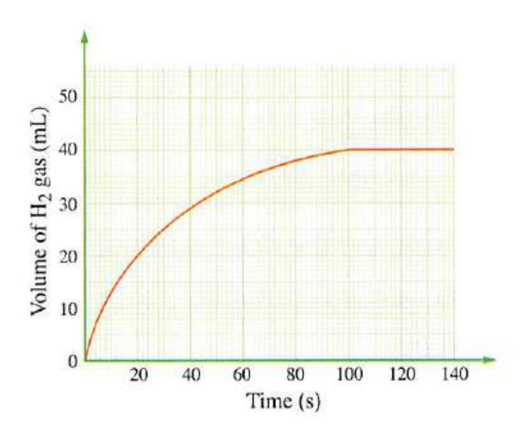
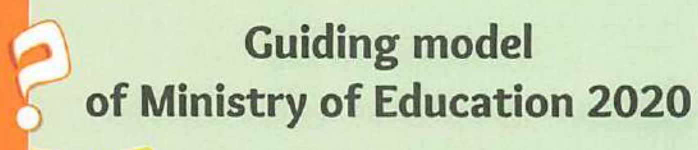


Open Book Exam model 21



Answered

Choose the correct answer for the following questions :

1. What is the number of the atoms in 1 mol of methanol CH_3OH ?
   (a) 6 atoms
   (b) 6.2×10^{23} atoms
   (c) 12×10^{23} atoms
   (d) 3.6×10^{24} atoms

2. Ammonia gas reacts with oxygen gas according to the following unbalanced equation : $NH_3 + O_2 \longrightarrow NO_2 + H_2O$
   What is the number of moles of oxygen in the balanced equation ?
   (a) 1 mol (b) 3 mol (c) 4 mol (d) 7 mol

3. Heating iron pyrite ore FeS_2 (roasting) is represented by the following unbalanced equation : $FeS_2 + O_2 \longrightarrow SO_2 + Fe_2O_3$
   What are the coefficients of the reactants and the products respectively ?
   (a) 4, 2, 8, 7 (b) 2, 4, 7, 8 (c) 2, 11, 7, 8 (d) 4, 11, 8, 2

4. Doctors advise taking vitamin C ($C_6H_8O_6$) to avoid catching cold.
   What is the number of moles of vitamin C in 528 g sample of it ? [C = 12 , H = 1 , O = 16]
   (a) 2 mol (b) 3 mol (c) 4 mol (d) 5 mol

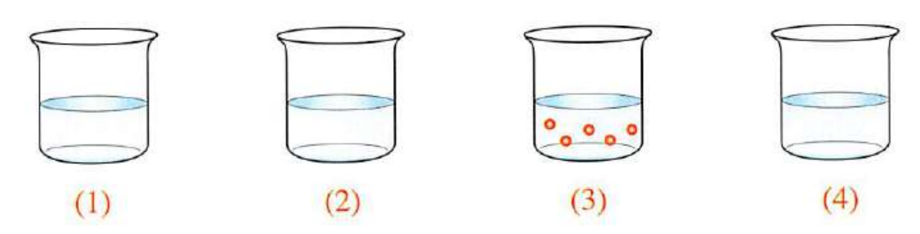
5. Which of the following turns the colour of litmus indicator into blue ?
   (a) Vinegar.
   (b) Baking soda solution.
   (c) Orange juice.
   (d) Soft drink.

6. Acids are the main cause of the corrosion of the teeth enamel, so calcium monophosphate $Ca(H_2PO_4)_2$ which is found in the teeth enamel is a(an) ....
   (a) basic substance.
   (b) amphoteric substance.
   (c) acidic substance.
   (d) neutral substance.

7. Which of the following acids does not form acidic salts ?
   (a) Phosphoric acid.
   (b) Carbonic acid.
   (c) Hydrochloric acid.
   (d) Sulphuric acid.

8 Four beakers, each of them contains 500 mL of water, and the amount of sugar present in each of them is different as shown in the opposite table :

Beaker (1)	Beaker (2)	Beaker (3)	Beaker (4)
150 g	250 g	450 g	0.5 g



What is the number of the beaker which contains a saturated solution ?

(a) (1)
(b) (2)
(c) (3)
(d) (4)

9 Aluminum reacts with hydrochloric acid according to the equation :

$$2Al + 6HCl \longrightarrow Al_2Cl_6 + 3H_2$$

What is the mass of hydrogen produced from the reaction of 25 g of aluminum with excess of hydrochloric acid ? [Al = 27 , H = 1]

(a) 0.41 g
(b) 1.2 g
(c) 1.8 g
(d) 2.8 g

10 The following reaction was carried out using 5 mol of each reactant :

$$2KMnO_4 + 5Hg_2Cl_2 + 16HCl \longrightarrow 10HgCl_2 + 2MnCl_2 + 2KCl + 8H_2O$$

What is the limiting reactant of this reaction ?

(a) $KMnO_4$
(b) HCl
(c) H_2O
(d) Hg_2Cl_2

11 In the opposite equation : $HF + H_2O \longrightarrow H_3O^+ + F^-$

Which of the following is correct ?

(a) H_2O represents the base, HF represents the conjugate acid.
(b) H_2O represents the acid, HF represents the conjugate base.
(c) HF represents the acid, F^- represents the conjugate base.
(d) HF represents the base, H_3O^+ represents the conjugate acid.

12 **An ionic compound is composed of 29.08% of sodium, 40.56% of sulphur and 30.36% of oxygen.**

What is the formula of sulphur ion in this compound ? [Na = 23 , S = 32 , O = 16]

(a) $S_2O_3^{2-}$

(b) $S_2O_4^{2-}$

(c) $S_2O_5^{2-}$

(d) $S_2O_6^{2-}$

13 **The following 5 incomplete equations represent neutralization reactions of acids with bases in aqueous solutions :**

(1) $CH_3COOH + NaOH \longrightarrow$

(2) $HNO_3 + Mg(OH)_2 \longrightarrow$

(3) $H_3PO_4 + Ba(OH)_2 \longrightarrow$

(4) $HCl + KOH \longrightarrow$

(5) $H_2CO_3 + LiOH \longrightarrow$

The ionic equation : $H^+ + OH^- \longrightarrow H_2O$ represents ....

(a) Reaction (1) only.

(b) Reactions (1) , (4) and (5).

(c) Reactions (2) and (3) only.

(d) Reaction (4) only.

14 **The reaction of nitric acid with aluminum hydroxide is represented by the net ionic equation** ....

(a) $3H^+_{(aq)} + Al(OH)_{3(s)} \longrightarrow Al^{3+}_{(aq)} + 3H_2O_{(\ell)}$

(b) $3HNO_{3(aq)} + Al(OH)_{3(s)} \longrightarrow Al(NO_3)_{3(aq)} + 3H_2O_{(\ell)}$

(c) $HNO_{3(aq)} + OH^-_{(aq)} \longrightarrow NO^-_{3(aq)} + H_2O_{(\ell)}$

(d) $H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(\ell)}$

Open Book Exam model 22

Guiding model of Ministry of Education 2021

Answered

- Choose the correct answer for the following questions :

1 The solubility of a substance (A) decreases by increasing the temperature, so if the solubility of substance (A) in water is (10 g / 200 g of H_2O) at 30°C What is the value of its solubility at 60°C ?

(a) 15 g / 200 g
(b) 5 g / 200 g
(c) 5 g / 100 g
(d) 10 g / 100 g

2 pH value of the solution which results from the dissolution of potassium acetate in water ....

(a) increases.
(b) equals 2
(c) decreases.
(d) equals 7

3 A case of coronary artery blockage can be treated by using ....

(a) bucky balls.
(b) carbon nanotubes.
(c) nanorobots.
(d) nanoshell.

4 The opposite table shows the diameter of the particles of some mixtures in nanometers.
Which of these mixtures its particles can be distinguished by naked eye ?

Mixture	Particle's diameter (nm)
(A)	1200
(B)	900
(C)	0.5
(D)	0.25

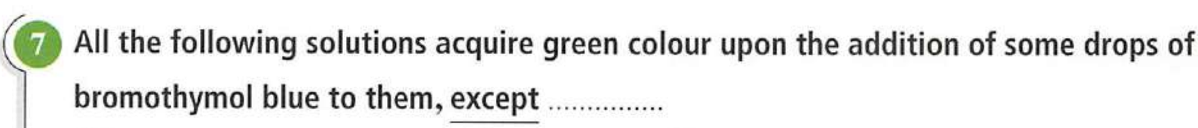
(a) (C).
(b) (D).
(c) (A).
(d) (B).

5 The mass of 1 molecule of methane CH_4 gas in grams equals .... [C = 12 , H = 1]

(a) 2.65×10^{23}
(b) 2.65×10^{-23}
(c) 26.5×10^{-23}
(d) 6.02×10^{-23}

6 When 78 g of potassium combine with 16 g of oxygen by heating, a compound is formed, its chemical formula is .... [K = 39 , O = 16]

(a) KO_2
(b) K_2O_2
(c) K_2O
(d) KO



7 All the following solutions acquire green colour upon the addition of some drops of bromothymol blue to them, except ....

(a) KNO_3
(b) CH_3COONa
(c) Na_2SO_4
(d) $NaCl$

8 Iron reacts with sulphur as follows : $Fe_{(s)} + S_{(s)} \longrightarrow FeS_{(s)}$

If 0.5 mol of sulphur had reacted with iron, and a mass of sulphur remained.

What is the reacting mass of iron ? [Fe = 56]

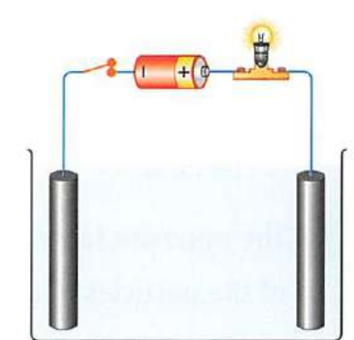
(a) 28 g
(b) 112 g
(c) 20 g
(d) 58 g

9 The acid which yields more than one type of salts is ....

(a) HNO_3
(b) CH_3COOH
(c) $HClO_4$
(d) $C_2H_2O_4$

10 In the illustrated electrical circuit :

Which of the following solutions when being placed in the beaker yields the dimmest light of the light bulb ?



(a) $NaOH_{(aq)}$
(b) $NH_4OH_{(aq)}$
(c) $KOH_{(aq)}$
(d) $KNO_{3(aq)}$

11 Which of the following equally concentrated solutions, its freezing point is the least ?

(a) $NaCl_{(aq)}$
(b) $C_6H_{12}O_{6(aq)}$
(c) $Na_2CO_{3(aq)}$
(d) $AlCl_{3(aq)}$

12 The components of the wireless nano devices are connected with wires ....

(a) whose particles dimensions are 3 m, 2 nm, 1 nm
(b) whose three dimensions are in the nanoscale.
(c) which have one nano dimension.
(d) whose particles dimensions are 3 nm, 2 m, 1 nm

13 4 substances (A), (B), (C) and (D), the dimension of each of them is as follows :

(A) : 12 nm

(B) : 50×10^{-5} m

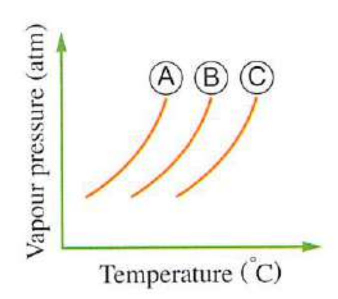
(C) : 80×10^{-9} m

(D) : 1×10^{-9} m

Which of these previous substances does not exhibit unique properties of the nanomaterials ?

(a) (A).
(b) (B).
(c) (D).
(d) (C).

14 The opposite graphical figure represents the relation between the vapour pressure and the temperature of several solutions :



Substance	Number of moles	Volume of solution
Na_2CO_3	0.3	1 L
NaCl	0.4	1 L
KNO_3	0.5	1 L

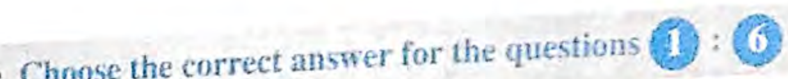
According to the data in this table, ...

(a) substance (A) represents NaCl, and substance (B) represents KNO_3
(b) substance (A) represents KNO_3, and substance (B) represents NaCl
(c) substance (A) represents Na_2CO_3, and substance (B) represents KNO_3
(d) substance (A) represents NaCl, and substance (B) represents Na_2CO_3

Booklet model 1

Exams 2022

The guiding model of the ministry of [illegible]tion



1 Which of the following solutions has higher boiling point ? ....

(a) 1 M sodium carbonate.

(b) 2 M sodium carbonate.

(c) 1 M iron (III) chloride.

(d) 2 M iron (III) chloride.

2 Number of atoms in half a mole of formaldehyde HCHO equals ....

(a) Avogadro's number.

(b) $\frac{1}{2}$ Avogadro's number.

(c) 2 × Avogadro's number.

(d) $\frac{1}{4}$ Avogadro's number.

3 On dissolving 55.5 g of calcium chloride $CaCl_2$ in water to form a solution its volume = 0.5 L , the concentration of this solution equals .... [Ca = 40 , Cl = 35.5]

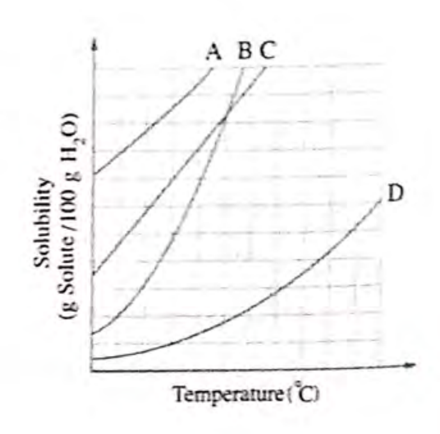
(a) 1 M (b) 0.5 M (c) 2 M (d) 1.5 M

4 An experiment was carried out to find the molecular formula of an unknown compound which contains three elements (A), (B) and (C), it was found that the mass percentage of the element (A) is 40% and that of the element (B) is 12%, what is the molecular formula of this compound, Knowing that it is also the empirical formula ? .... [A = 40 , B = 12 , C = 16]

(a) ABC_3 (b) A_3BC

(c) AB_3C (d) A_2B_2C

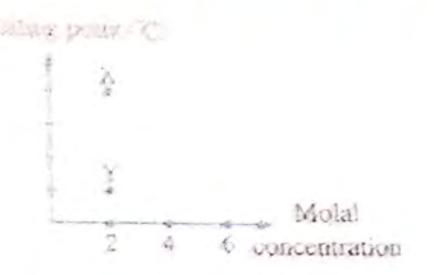
5 The opposite graph represents the relation between the solubility of some substances and the temperature, which of these substances its solubility increases with a higher extent by increasing the temperature of the solvent ? ....

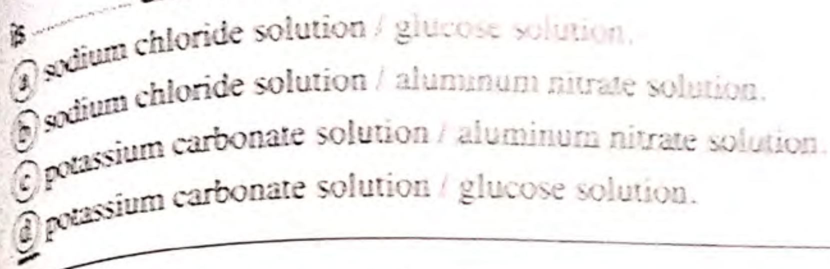


(a) A (b) B

(c) C (d) D

In the opposite graph, if the solutions (X), (Y) have the same molal concentration, So the solution (X) is .... and the solution (Y) is





ⓐ sodium chloride solution / glucose solution.

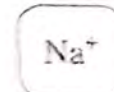
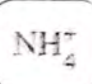
ⓑ sodium chloride solution / aluminum nitrate solution.

ⓒ potassium carbonate solution / aluminum nitrate solution.

ⓓ potassium carbonate solution / glucose solution.

Through the following radicals :

CH_3COO^-	SO_4^{2-}	Na^+	NH_4^+

Deduce the chemical formula of the salt, which dissolves in water forming a solution with pH value higher than 7

pH > 7 So solution is alkaline.
CH_3COONa (Sodium acetate)
→ weak acid acetic acid
Na → strong base (NaOH)

Arrange the following acids ascendingly according to their number of basicity :

H_3BO_3 / HCN / H_2SO_3

$HCN < H_2SO_3 < H_3BO_3$

Deduce the conjugate acid and the base according to Brönsted - Lowry theory in the following equation : $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$

H_3O^+ => Conjugate acid, H_2O => base

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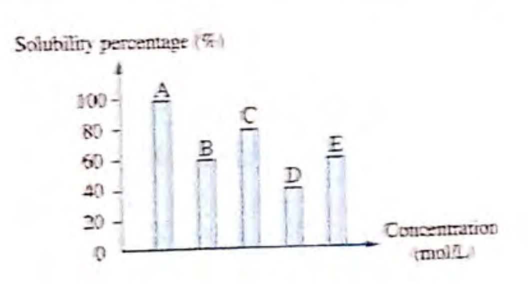
10 In the opposite graph Which of the illustrated compounds (A, B, C, D, or E) represents the ionization of an organic acid in water ? Why ?



Compound (D), as organic acid are weak acids, that are not complete ionized in water

11 **Calculate the number of moles of iron (III) oxide Fe_2O_3** produced from heating 456 g of iron (II) sulphate $FeSO_4$ according to the equation : [Fe = 56 , S = 32 , O = 16]

2mole → 1mole

304 → 1mole

456 → ?

? = 456/304 = 1.5 mole

$$2FeSO_4 \xrightarrow{\Delta} Fe_2O_3 + SO_2 + SO_3$$

2FeSO4 → Fe2SO3

2mole → 1mole

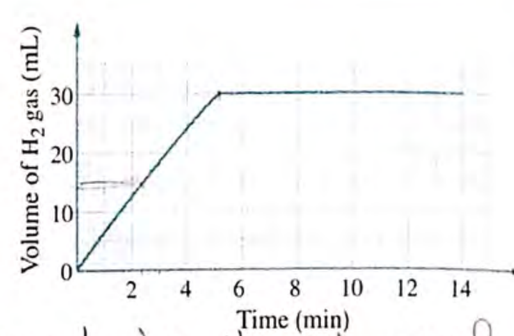
2(56+32+64) → 1(56×2+16×3)

304 → 160

456 → ?

? = 456×160/304 = 240gm ⇒ no. mole = 240/160 = 1.5 mole

12 The opposite graph represents the relation between the volume of hydrogen gas which is evolved from the reaction of a limited amount of magnesium with excess of hydrochloric acid by time, **deduce the time of consumption of half the amount of magnesium.**



All amount of magnesium is Consumed when the volume of hydrogen gas become Constant (30mL) at 5 min

half amount of magnesium Consumed when H2 gas become (15 ml) after ⇒ 2.4 min

Booklet model 2

Rate your level

Superior	Remarkable	above average	Weak
from 20 marks to 18 marks	from 17 marks to 14 marks	from 13 marks to 10 marks	less than 10 marks

Choose the correct answer for the questions .

1 Which of the following measuring relations is incorrect ? ....

ⓐ 1 microliter = 1×10^{-6} L

ⓑ 1 gram = 1×10^{-6} kg

ⓒ 1 liter = 10^3 mL

ⓓ 10^2 centigram = 1 g

2 What is the mass percentage of hydrogen in chlorous acid $HClO_2$? ....

[H = 1 , Cl = 35.5 , O = 16]

ⓐ 1.92% ⓑ 25% ⓒ 23.4% ⓓ 1.46%

3 What is the number of nitrogen atoms in 240 g of ammonium nitrate ? .... **atoms.**

[N = 14 , H = 1 , O = 16]

ⓐ 2×10^{23} ⓑ 6.02×10^{23} ⓒ 1.81×10^{24} ⓓ 36.12×10^{23}

4 What is the total number of moles of H^+ which are found in 2.5 L phosphoric acid its concentration is 0.7 M ? ....

ⓐ 0.233 mol ⓑ 2.1 mol ⓒ 5.25 mol ⓓ 3 mol

5 Which of the following solutions has higher boiling point ? ....

ⓐ 0.1 M HI solution.

ⓑ 0.1 M $(NH_4)_3PO_4$ solution.

ⓒ 0.1 M NH_4Cl solution.

ⓓ 0.1 M NaI solution.

6 Which of the following colloids is formed from dispersion of liquid in solid ? ....

ⓐ Hair gel, cheese and butter.

ⓑ Milk, hair gel and blood.

ⓒ Aerosol, jelly and mayonnaise.

ⓓ Mayonnaise, hair gel and cheese.

7 35.5 mL aqueous solution contains 22.5 g of sucrose (its molar mass = 342 g/mol) What is the molar concentration of this solution ? ....

ⓐ 0.0657 M ⓑ 1.85×10^{-3} M ⓒ 1.85 M ⓓ 0.104 M

8 10 g of hydrogen gas react with excess of oxygen gas according to the equation :

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(v)}$$

What is the reacted volume of oxygen gas (at STP) and the mass of the produced water vapour in this reaction ? ....

Choices	Reacted volume of O_2	Mass of H_2O
(a)	2.5 L	5 g
(b)	5 L	5 g
(c)	56 L	90 g
(d)	80 L	120 g

9 Each of the following acids when dissolves in water, it can yield more than one proton, except ....

(a) oxalic acid. (b) sulphuric acid. (c) carbonic acid. (d) acetic acid.

10 What does happen when a small crystal of the solute substance is put in its supersaturated solution ? ....

(a) The crystal dissolves in the solution only.
(b) The solution becomes saturated only.
(c) The molecules of the solute will be collected around the crystal only.
(d) (b), (c) together.

11 "Carbon is found in the form of graphite and diamond",
Mention three other forms in which carbon can be found.

Single atom – Carbon nano tubes → Bucky ball

12 Calculate the molar mass of calcium phosphate compound. [Ca = 40 , P = 31 , O = 16]

$Ca_3(PO_4)_2$ = (3×40) + 2(31 + 64)
120 + 190 = 310 g/mol

13 Complete the following equation, and rewrite it in the form of an ionic equation :

$$Fe(NO_3)_{2(aq)} + (NH_4)_2CO_{3(aq)} \longrightarrow FeCO_{3(s)} + 2NH_4NO_{3(aq)}$$

$Fe^{2+} + 2NO_3^- + 2NH_4^+ + CO_3^{2-} \longrightarrow FeCO_3 + 2NH_4^+ + 2NO_3^-$

$Fe^{2+} + CO_3^{2-} \longrightarrow FeCO_{3(s)}$

2 marks

14 What is the type of the aqueous solution of sodium nitrate salt (acidic, basic or neutral) ? Explain.

Neutral, as it Salt Produced from reaction between strong acid (HNO_3) and strong base (NaOH).

2 marks

15 In this reaction : $NH_{3(g)} + H_2O_{(l)} \rightleftharpoons NH^{+}_{4(aq)} + OH^{-}_{(aq)}$

What does each of the following represent in the light of Lewis concept of acids and bases :

(1) Ammonia gas.

Lewis base as it donor with a pair of electron

(2) Water.

Lewis acid as it accepts a pair of electron

1 mark

16 Sulphuric acid is added to barium hydroxide until the reaction is completed, write the symbolic equation which represents this reaction, with illustrating the physical state of barium hydroxide only in this reaction, then explain which is larger in number :

the ions which are present in the beginning of the reaction or the ions which are present at the end of the reaction ?

$Ba(OH)_{2(aq)} + H_2SO_4 \rightarrow BaSO_{4(s)} + 2H_2O$

The greater number of ions at the begining of reaction as Ba^{2+}, SO_4^{2-} leave the reaction and precipitate at the end of reaction

2 marks

17 Calculate the percentage of the actual yield of zinc sulphate, if its calculated (theoretical) mass = 1.358 g and its actual mass = 1.146 g

% actual yield = $\frac{\text{actual mass}}{\text{Theoritical mass}} \times 100$

$= \frac{1.146}{1.358} \times 100 = 84.39\ \%$

1 mark

Booklet model 3

• Choose the correct answer for the questions 1 : 10 .

1 In bucky ball, every carbon atom is attached to .... other carbon atoms.

(a) 1 (b) 2 (c) 3 (d) 4

2 Each of the following is a solution, except ....

(a) iron filings with sulphur powder.
(b) hydrogen chloride gas in water.
(c) iodine in benzene.
(d) silver in mercury.

3 Two closed vessels contain chlorine gas at the same conditions of temperature and pressure, so if the first vessel whose volume = 1.3 L contains 6.7 mol of gas, what is the number of moles in the second vessel whose volume = 2.33 L ? ....

(a) 0.452 mol (b) 3.74 mol (c) 12 mol (d) 20.3 mol

4 Which of the following aqueous solutions has lower freezing point ? ....

(a) 0.1 m $(NH_4)_2SO_4$
(b) 0.1 m $MnSO_4$
(c) 0.1 m NaF
(d) 0.1 m CH_3OH

5 In which of these choices $H_2PO_4^-$ acts as an acid ? ....

(a) $H_3PO_4 + H_2O \rightleftharpoons H_3O^+ + H_2PO_4^-$

(b) $H_2PO_4^- + H_2O \rightleftharpoons H_3O^+ + HPO_4^{2-}$

(c) $H_2PO_4^- + OH^- \rightleftharpoons H_3PO_4 + O^{2-}$

(d) An ion can't act as an acid in any chemical reaction.

6 All of the following are colloids, except ....

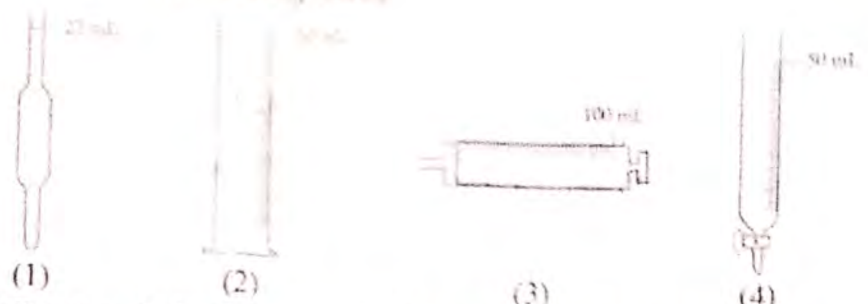
(a) air in whipped egg whites.
(b) air in cotton candy.
(c) ground maize powder in water.
(d) oxygen in atmospheric air.

7 Molal solution contains 1 mol of the solute in ....

(knowing that water density = 1 kg/L)

(a) 1000 mL of the solvent.
(b) 1000 g of the solution.
(c) 1 L of water.
(d) 22.4 L of the solution.

8 Here are four different measuring tools



(1) (2) (3) (4)

Which of the following choices represents the proper use for the measuring tool ? ....

Choices	Measuring tool	Used in
(a)	(1)	Transferring 20 mL of an alkali to carry out a titration.
(b)	(2)	Collecting 75 mL of the gas produced from a thermal decomposition reaction.
(c)	(3)	Adding 1 mL of an acid to calcium carbonate.
(d)	(4)	Adding 15.6 mL of an acid to carry out a titration.

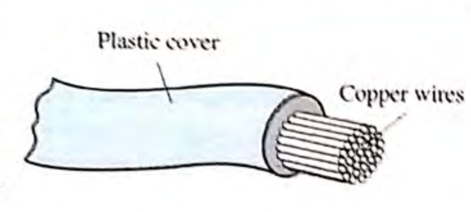
9 On dissolving NH_4ClO_4 acid in water, the formed solution is .... NH_4OH weak , $HClO_4$ perchloric acid

(a) acidic. (b) neutral. (c) basic. (d) amphoteric.

10 What is the meaning of that nitric acid is a strong acid ? ....

(a) It dissolves in water and H^+ concentration in the solution equals OH^- concentration.
(b) It does not ionize in water on dissolving in it.
(c) It ionizes completely in water into H^+ , NO_3^- ions.
(d) It is neutralized by a strong base only.

11 The opposite figure represents a section in a flexible copper cable, it easily bends with the bends of the plastic pipes inside walls and ceilings, is it useful to replace copper which is used in the manufacture of cable wires with any of the following ? Explain your answer.



(1) Copper nano wires.
No, Bec, The hardness of copper increase by decreasing volume of its particles to nano scale and it can't be bend

(2) Single - wall carbon nano tubes.
Yes, as the ability of carbon nano tubes to conduct electricity is larger than copper

2 marks

12 Calculate the mass of oxygen in 0.52 g of sodium bicarbonate.

[Na = 23 , H = 1 , C = 12 , O = 16]

NaHCO3 ⟶ 3O
(23+1+12+48) ⟶ 3×16
0.52 ⟶ ?
? = 0.52×48 / 84 = 0.2971 gm

1 mark

13 The opposite graph shows the solubility curve of four different substances A , B , C and D, which of these substances its solubility is :

(1) As high as possible at 10°C

(D)

(2) As low as possible at 90°C

(D)

1 mark

14 Compare between hydrogen chloride gas and glucose by filling in the spaces in the following table :

Points of comparison	Hydrogen chloride gas	Glucose
(1) Solubility in water	Soluble	Soluble
(2) Ionization in water	Complete ionization	Not ionized

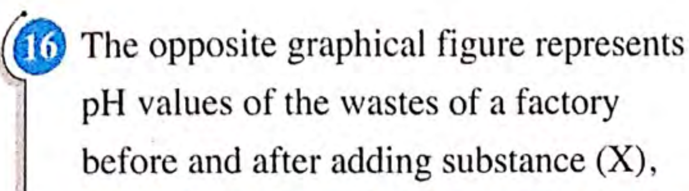
1 mark

15 Choose, with explanation, one or more of the following substances that can be present in a test tube which contains phosphoric acid :

PO_4^{3-} | HPO_4^{2-} | $H_2PO_4^-$ | H_3PO_4

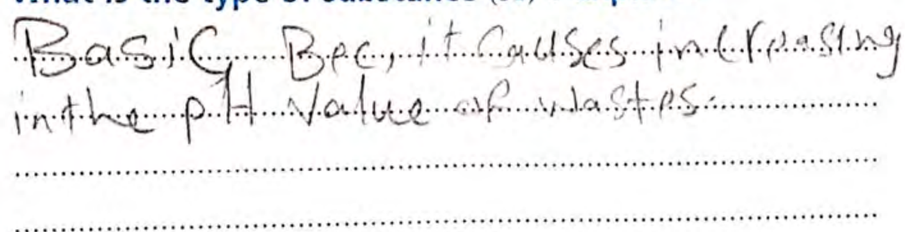
All of them, as phosphoric acid is a tribasic acid, which can present in form of molecules with ionize

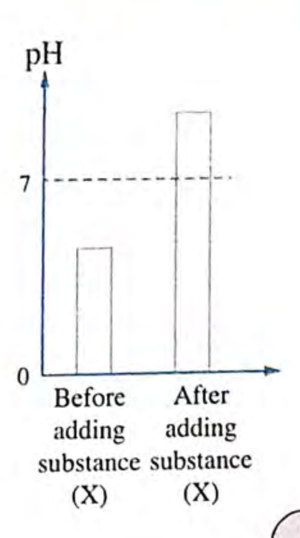
2 marks



16 The opposite graphical figure represents pH values of the wastes of a factory before and after adding substance (X),

What is the type of substance (X) ? Explain.





1 mark

17 **Rewrite the following word equation as a balanced symbolic equation :**

Magnesium nitrate + Potassium phosphate ⟶ Magnesium phosphate + Potassium nitrate

$a Mg(NO_3)_2 + {}^{b}K_3PO_4 \longrightarrow {}^{c}Mg_3(PO_4)_2 + {}^{d}KNO_3$

2 marks

Mg ⇒ a = 3C
N ⇒ 2a = d
O ⇒ 6a + 4b = 8C + 3d
K ⇒ 3b = d
P ⇒ b = 2C

a = 1, C = 1/3, b = 2/3, d = 2 ×3 ⇒ a = 3, C = 1, b = 2, d = 6

$3Mg(NO_3)_2 + 2K_3PO_4 \longrightarrow Mg_3(PO_4)_2 + 6KNO_3$

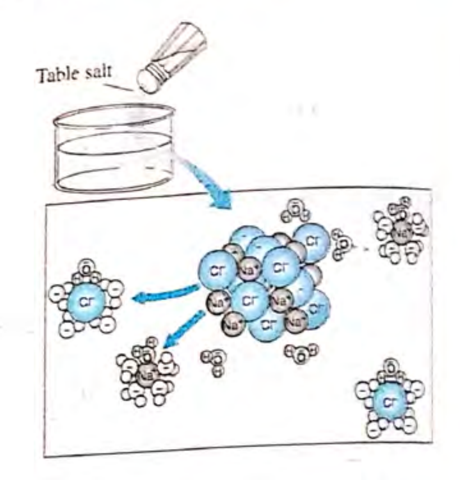
Booklet model 4

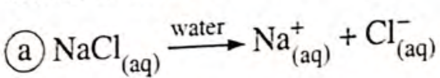
Choose the correct answer for the questions 1 : 10 .

1 **The screen of the mobile phone is covered with nano liquid to form a thin layer on its surface to protect it from scratching and breaking, what is the type of the material used in manufacture of this nano liquid ? ....**

(a) Colloidal substance.
(b) One-dimensional nano substance.
(c) Suspension substance.
(d) Two-dimensional nano substance.

2 **Which of the following equations represents the process of dissolving the table salt in water which is illustrated in the figure ? ....**





(a) $NaCl_{(aq)} \xrightarrow{water} Na^+_{(aq)} + Cl^-_{(aq)}$
(b) $NaCl_{(s)} \xrightarrow{water} Na^+_{(s)} + Cl^-_{(s)}$
(c) $NaCl_{(s)} \xrightarrow{water} Na^+_{(aq)} + Cl^-_{(aq)}$
(d) $NaCl_{(aq)} \xrightarrow{water} Na^+_{(s)} + Cl^-_{(g)}$

3 **The ionic equation which represents the reaction of sodium hydroxide solution with hydrochloric acid does not contain each of ....**

(a) Na^+ , Cl^-
(b) H^+ , OH^-
(c) Na^+ , OH^-
(d) H^+ , Cl^-

4 **In the following reaction : $6Li_{(s)} + N_{2(g)} \longrightarrow 2Li_3N_{(s)}$**
What is the number of moles of lithium required to react with excess of nitrogen gas to produce 0.6 mol of lithium nitride ? ....

(a) 0.2 mol
(b) 0.3 mol
(c) 0.4 mol
(d) 1.8 mol

5 **Each of the following is among the properties of lactic acid, except that it ....**

(a) is found in yaughurt.
(b) is an organic acid.
(c) reacts with sodium to form salt and water.
(d) is a weak acid.

6. The following compounds formulas :

$$KNO_3 , Pb(NO_3)_2 , Fe(NO_3)_3$$

indicate that the nitrate group is ....

(a) monovalent only.
(b) divalent only.
(c) trivalent only.
(d) mono, di, and trivalent.

7. Which of the following examples is an application of Avogadro's law ? ....

(a) When 3 balloons contain equal numbers of H_2 , O_2 and Cl_2 molecules, their volumes will be equal at the same temperature and pressure.
(b) The balloon which contains H_2 gas, its volume increases by increasing temperature at constant pressure.
(c) The volume of a balloon decreases with decreasing the number of moles of Ar gas in it at constant temperature and pressure.
(d) The volume of a piston which contains neon decreases by increasing the pressure at constant temperature.

8. In the opposite table
Water that contains a little amount of acetone, its boiling point is ....

Substance	Boiling point
Acetone	56°C
water	100°C

(a) 56°C
(b) 78°C
(c) 100°C
(d) 104°C

9. Which of the following choices represents dissolving table sugar (its molar mass = 342 g/mol) in water and dissolving table salt (its molar mass = 58.5 g/mol) in water ? ....

(a) Both form liquid in solid solutions.
(b) Both are electrolytes.
(c) Freezing point of the salt solution is lower than the freezing point of sugar solution at the same concentration.
(d) On adding X mass of each to the same volume of water, sugar solution concentration will be higher than that of salt solution.

10. On neutralizing acetic acid with sodium hydroxide solution, ... is formed.

(a) alkaline solution.
(b) acidic solution.
(c) neutral solution.
(d) gaseous solution.

11 The opposite figures (X) , (Y) represent two sections in two measuring tools :

- **Tool (X) :** is used in measuring a definite volume of an acid accurately.
- **Tool (Y) :** is used in estimating the increase in the volume of water on dipping a piece of iron in it,

what is the name of each tool ? What is the volume of the measured liquid in each of them ?

X = Burette , volume = 27.8 ml

Y => Graduated cylinder => 44 ml

1 mark

12 In the opposite figure which represents the solubility curve of potassium nitrate in water, on stirring 75 g of potassium nitrate in 100 g of water at 100°C, no precipitate is formed and when the solution is cooled to 30°C a precipitate appears.

What is the type of solution (unsaturated / saturated / supersaturated) ? Explain your answer and calculate the precipitated mass of potassium nitrate after cooling to 30°C approximately.

Supersaturated / as on Cooling the Solution, the excess Solute particles precipitated.

Quantity = 75 − 45 = 30 gm

2 marks

13 **Calculate the mass percentage** of carbon in oxalic acid. [C = 12 . O = 16 . H = 1]

COOH
|
COOH → 2C

[(2×12) + (2×2×16) + (2×1)] → 2×12

90 gm = 24 gm

Percentage = $\frac{24}{90}$ ×100 = 26.67 %

1 mark

14 One of the students carried out an experiment to find out the type of the mixture formed by shaking mercury in petroleum oil.

Experiment	Observation
(1) On falling a beam of light on the mixture	The light is scattered
(2) On leaving the mixture for some minutes after shaking	Mercury precipitates in oil
(3) On pouring the mixture in a funnel contains a filter paper	Mercury is separated from oil

Depending on these observations, recognize the type of this mixture, with explaining.

- Is it a solution ?

Not Solution, as Solution isn't Scattering the light falling on it while mixture do.

- Is it a colloid ?

Not Colloid, as Colloid Particles don't precipitates after shaking and it Components Can't be separated by filtration

- Is it a suspension ?

Yes, as Suspension Scatters light and it's Particles precipitates after shaking and can separate by filtration

2 marks

15 **Illustrate by a symbolic equation only** the definition of an acid in the light of Arrhenius theory, **what is the change that happens** in water which contains some drops of methyl orange indicator by adding the acid to it ?

$HNO_3 \longrightarrow H^+ + NO_3^-$

by adding acid to methyl orange it's Color Change into red

1 mark

16 **Among the famous chemical compounds :**

- Iron (II) oxide. FeO
- Calcium oxide. CaO

(1) Illustrate by symbolic equations only a similarity between the two compounds.

$FeO_{(s)} + 2HCl_{(aq)} \longrightarrow FeCl_{2(aq)} + H_2O_{(l)}$

$CaO_{(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + H_2O_{(l)}$

Both of them are metal oxide which are basic oxide and react with acid gives salt + water

(2) Why is iron (II) oxide described as a base and not an alkali, while calcium oxide is described as a base and an alkali ?

FeO is base as it not soluble in water.

, While CaO is a base and alkali as it dissolves in water

2 marks

17 **Calculate the molar concentration of** a solution of the table salt its volume = 1.5 L and contains 26.325 g of sodium chloride where its molar mass = 58.5 g/mol

No. moles = $\frac{\text{mass}}{\text{molar mass}}$

= $\frac{26.325}{58.5}$ = 0.45 mol.

Mararity = $\frac{\text{no. moles}}{\text{volume of solution}}$ = $\frac{0.45}{1.5}$ = 0.3 M

1 mark

Booklet model 5

Choose the correct answer for the questions **1 : 10 .** 10 marks

1 Which of the following tools shown in figures can be used to transfer the highly dangerous liquids ? ....

ⓐ ⓑ ⓒ ⓓ

2 You have four solutions of equal concentrations, which of them conducts electric current by a higher degree ? ....

ⓐ HF ⓑ HBr ⓒ HCN ⓓ H_2SO_3

3 Nitric acid is similar to acetic acid in that both are .... acids.

ⓐ organic ⓑ mineral ⓒ strong ⓓ monobasic

4 What is the empirical formula of the compound that contains 85.6% carbon and 14.4% hydrogen ? .... [C = 12 , H = 1]

ⓐ CH ⓑ CH_2 ⓒ CH_3 ⓓ CH_4

5 Which of the following is not a strong base ? ....

ⓐ $Ca(OH)_2$ ⓑ KOH ⓒ NH_3 ⓓ LiOH

6 What is the mass of solute in a solution of ammonium chloride, its volume is 256 mL and its concentration is 0.9 M ? .... [N = 14 , H = 1 , Cl = 35.5]

ⓐ 12.3 g ⓑ 16.3 g ⓒ 175 g ⓓ 215 g

7 What is the number of types of salts that phosphoric acid can form ? ....

ⓐ 1 ⓑ 2 ⓒ 3 ⓓ 4

8 In the following equation :

$$C_6H_5NH_{2(aq)} + H_2O_{(l)} \rightleftharpoons C_6H_5NH^+_{3(aq)} + OH^-_{(aq)}$$

Reactants and products can be classified as follows : ....

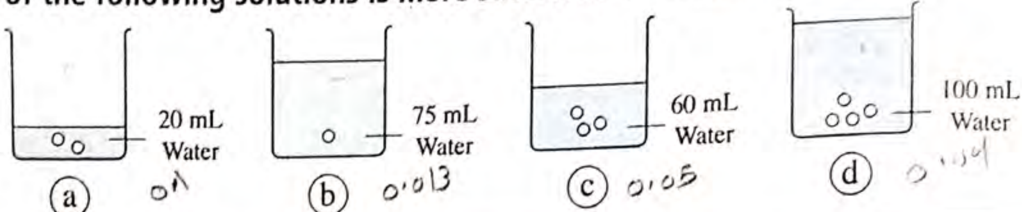
ⓐ acid + base $\rightleftharpoons$ acid + base. ⓑ acid + base $\rightleftharpoons$ base + acid.

ⓒ base + acid $\rightleftharpoons$ acid + base. ⓓ base + acid $\rightleftharpoons$ base + acid.

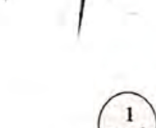
9 **The following acids : (H_3PO_4 / HCl / H_2SO_3)**
are arranged from weaker to stronger as follows : ....

(a) $HCl < H_3PO_4 < H_2SO_3$
(b) $HCl < H_2SO_3 < H_3PO_4$
(c) $H_2SO_3 < H_3PO_4 < HCl$
(d) $H_3PO_4 < H_2SO_3 < HCl$

10 **Which of the following solutions is more saturated ?** ....



11 **The opposite figure** shows a nanorobot that Dr. Magdi Yacoub dreams to use in his field to carry out operations without surgery.



Suggest an importance for the nanorobot.

removing blood Clots from blood vesseles, when it is introduced to blood stream without surgery

1 mark

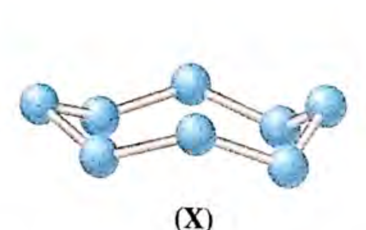
12 **Calculate the mass of each of solute and solvent** in potassium chloride solution its mass is 250 g and its concentration is 5%   % (m/m) = mass of solute / mass of solution × 100

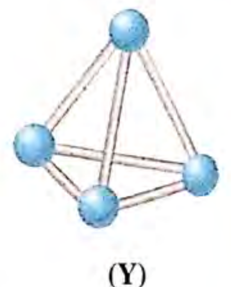
mass of solute = % (m/m) × mass of solution / 100 = 5 × 250 / 100 = 12.5 gm

mass of solvent = mass of solution − mass of solute = 250 − 12.5 = 237.5 gm

2 marks

13 **The opposite two figures represent** the structure of phosphorus and sulphur vapours (with no particular order) if you know that the gram atomic mass of phosphorus is 31 g/mol and that of sulphur is 32 g/mol :


(X)


(Y)

(1) **Which figure** represents the structure of phosphorus vapour molecule ?

figure (Y)

(2) **Calculate the molar mass** of the vapour of the two elements.

S8 = 8 × 32 = 256 gm/mol

P4 = 4 × 31 = 124 gm/mol

1 mark

14 Complete the following table with what is suitable of the following substances :

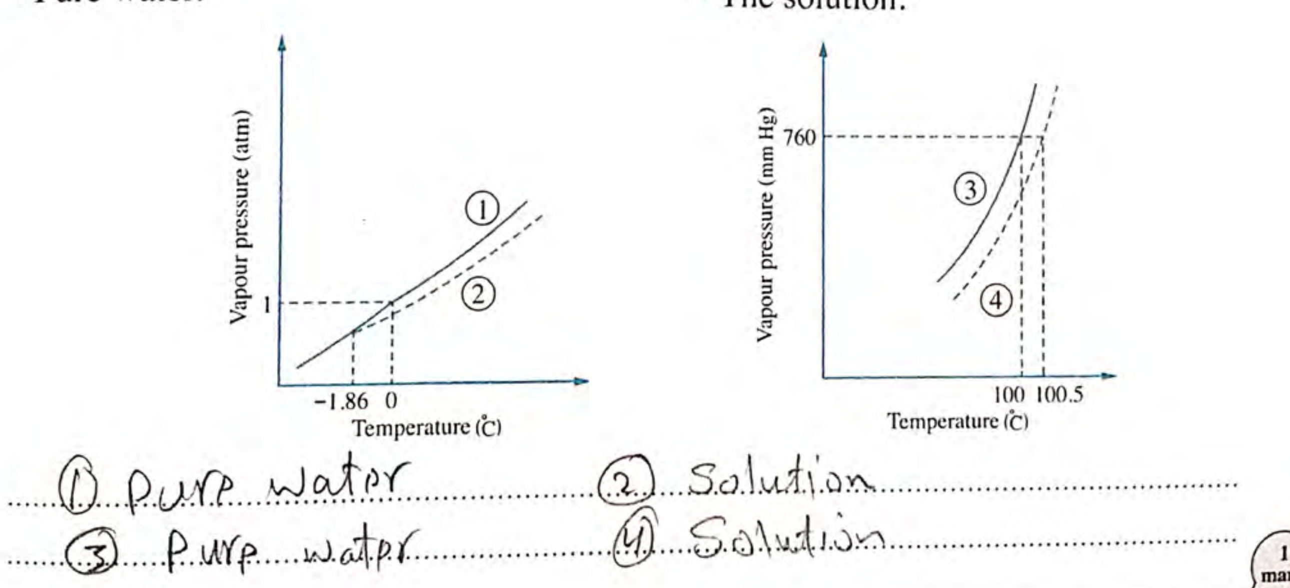
Gas	Liquid	Solid
Nickel chrome alloy	Atmospheric air	Sea water

Types of solution	Physical state of solute	Physical state of solvent	Example
(1) Gaseous solution	......Gas......	...Gas......	air......
(2) Liquid solution	......solid......	...liquid......	Seawater
(3) Solid solution	..Solid......	Solid......	nickelChrome alloy

2 marks

15 In the light of your knowledge about the relation between the vapour pressure and each of boiling and freezing points of each of pure water and the solution, replace the numbers shown on the following figures with what suits each of them from the terms :

- Pure water.
- The solution.



......① pure water...... ② Solution......

......③ pure water...... ④ Solution......

1 mark

16 The following ions can form several salts :

Na^+ | NH_4^+ | Cl^- | CO_3^{2-}

Conclude the chemical formula of the salt that dissolves in water forming :

(1) A solution its pH equals 7 (NaCl)

(2) A solution its pH is less than 7 NH4Cl

(3) A solution its pH is more than 7 (Na2CO3

2 marks

17 **Calculate the mass percentage** of hydrogen [H = 1] in magnesium bicarbonate compound, its molar mass is 146 g/mol

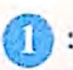
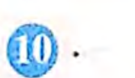
$Mg(HCO_3)_2 \longrightarrow 2H$

$146\ gm \longrightarrow 2\ gm$

mass of of H = $\frac{\text{mass of (H) in 1 mole}}{\text{molar mass of compound}}$ $\frac{2}{146} \times 100 = 1.36\ \%$

1 mark

Booklet model 6

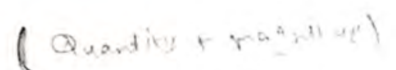
Choose the correct answer for the questions  :  .

1 **Which of the following expresses a quantitative measurement ?** ....

(a) Aluminum bar is longer than copper bar.

(b) The first solution is more concentrated than the second solution.

(c) The colour of the first solution is blue.

(d) The temperature of the second solution is 60°C 

2 **Which of the following is an application of Avogadro's postulate ?** ....

(a) oxygen atom is 16 times heavier than hydrogen atom.

(b) 1 cm^3 of each of Ar , O_2 , NH_3 gases contains the same number of molecules at 80k and 1 atm.

(c) Volume of hydrogen gas increases by increasing its number of moles at constant temperature and pressure.

(d) A mole of any gas such as CH_4 contains 22.4 L (at STP).

3 **What is the number of moles of hydrogen sulphide in 49.7 g sample of it ?** ....

[S = 32 , H = 1]

(a) 0.686 mol (b) 1.46 mol (c) 83.8 mol (d) 24.7 mol

4 **Which of the following acids is a strong acid ?** ....

(a) HF (b) KOH (c) $HClO_4$ (d) HClO

5 **On dissolving 16.4 g of HF in water, a solution its volume is 2×10^2 mL and its concentration is .... is formed.**

[H = 1 , F = 19]

(a) 0.82 M (b) 0.16 M (c) 0.08 M (d) 4.1 M

6 **What is the type of the compound which dissolves in water and does not dissolve in benzene ?** ....

(a) polar only.

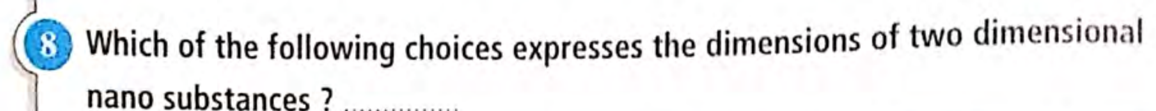
(b) nonpolar only.

(c) polar or nonpolar.

(d) polar or ionic.

7 The separating funnel showed in the opposite figure is used to separate the components of .... mixture.

(a) cobalt (II) chloride in water
(b) aqueous solution of cobalt (II) chloride in kerosene
(c) milk
(d) copper sulphate in water



8 Which of the following choices expresses the dimensions of two dimensional nano substances ? ....

Choices	Length	Width	Height
(a)	1.2×10^{-11} m	200×10^{-10} m	320×10^{-12} m
(b)	21×10^{-10} m	0.18×10^{-5} m	17.9×10^{-9} m
(c)	130×10^{-7} m	49×10^{-7} m	68×10^{-6} m
(d)	17×10^{-8} m	83×10^{-4} m	96×10^{-3} m

9 If the formula of antimony oxide is Sb_2O_3 and that of sodium phosphate is Na_3PO_4, what is the formula of antimony phosphate ? ....

(a) $SbPO_4$
(b) Sb_2PO_4
(c) $Sb_2(PO_4)_3$
(d) Sb_3PO_4

10 20 mL of carbon monoxide gas combust in excess of oxygen according to the equation :

$$2CO_{(g)} + O_{2(g)} \xrightarrow{\Delta} 2CO_{2(g)}$$

What is the produced volume of carbon dioxide gas (at STP) ? ....

(a) 20 mL
(b) 40 mL
(c) 60 mL
(d) 80 mL

11 A chemical reaction is expressed by the opposite symbolic equation :

$$aA + bB \longrightarrow cC + dD$$

What is the number of possible values of the value $\frac{c}{d}$? with explanation.

only one value, as the ratio of coffecients in the balanced equation is constant

1 mark

12 The following figures express the steps of preparation of the pure crystals of one of the salts :

(1) (2) (3) (4)

Mention the name of a salt can be prepared by this method. With explanation.

NaCl, Soluble salt, it soluble in water and can be obtained by evaporation of water from solution

1 mark

13 In the chemical reaction illustrated by the following equation :

$$CH_3COOH_{(aq)} + NH_{3(g)} \rightleftharpoons CH_3COO^-_{(aq)} + NH^+_{4(aq)}$$

Relate each compound or ion in the previous equation with the appropriate term of the following :

conjugate base	acid	conjugate acid	base

acid + base ⇌ conjugate base + conjugate acid

1 mark

14 In the reaction : $Ca_3(PO_4)_2 + 3H_2SO_4 \longrightarrow 3CaSO_4 + 2H_3PO_4$

129 g of $Ca_3(PO_4)_2$ was added to 4.4 g of H_2SO_4,

illustrate by chemical calculations the limiting reactant for this reaction.

$[Ca_3(PO_4)_2 = 310\ g/mol\ ,\ H_2SO_4 = 98\ g/mol]$

$Ca_3(PO_4)_2 \rightarrow 3CaSO_4$
1 mole → 3 mole
310 → 3 mole
129 → ?
? = $\frac{129 \times 3}{310}$ = 1.248 mol

$3H_2SO_4 \rightarrow 3CaSO_4$
3 mole → 3 mole
3×98 → 3 mole
294 → 3 mole
4.4 → ?
? = $\frac{3 \times 4.4}{294}$ = 0.044
H_2SO_4 consumed to produce less no. of $CaSO_4$ moles
H_2SO_4 is limiting reactant

2 marks

15 **Conclude the chemical formula** of rhenium chloride compound given that the percentage of rhenium Re in it is 63.6% [Re = 186.2 , Cl = 35.5]

assume mass of Compound = 100

	Re	Cl
mass	63.6	36.4
no. moles	$\frac{63.6}{186.2}$ = 0.341 mol	$\frac{36.4}{35.5}$ = 1.025 mol
Ratio	$\frac{0.341}{0.341}$ = 1	$\frac{1.025}{0.341}$ = 3 mol
Formula unit	$ReCl_3$	

2 marks

16 **What is the value** of 9.49 s in nanosecond unit ?

9.49 s = 9.49×10^9 ns

1 mark

17 If you have 1 mL of each of colourless hydrochloric acid and phenolphthalein indicator.

How to differentiate between them by one practical experiment ?

*** Experiment :**

adding alkali solution to each of them (NaOH)

*** Observation :**

HCl remains Colourless, Phenolphtalein Changes into pink

2 marks

Booklet model 7

Choose the correct answer for the questions 1 : 10 .

1 **Quantitative measurement ....**

(a) includes a numerical value and a measuring unit.
(b) doesn't include a numerical value.
(c) always includes a comparison.
(d) is achieved through practical experiments.

2 **All the chemical formulas of compounds shown in the following table are correct, except ....**

(a)	(b)	(c)	(d)
Aluminum sulphate	Calcium nitrate	Iron (III) bromide	Potassium sulphide
$Al_2(SO_4)_3$	$Ca(NO_3)_2$	Fe_3Br	K_2S

3 **An element (X) its gram atomic mass is 32 g/mol and its electronic configuration is (2 , 8 , 6), Another element (Y) its gram atomic mass is 35.5 g/mol and its electronic configuration is (2 , 8 , 7), What is the gram molecular mass of the compound produced from combining the atoms of the two elements (X) , (Y) ? ....**

(a) 67 g/mol (b) 99 g/mol (c) 103 g/mol (d) 134 g/mol

4 **Which of the following represents a pair of conjugate acid and base ? ....**

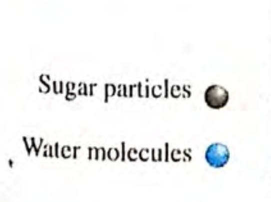
(a) H_3PO_4 , PO_4^{3-} (b) $H_2PO_4^-$, PO_4^{3-} (c) H_3PO_4 , HPO_4^{2-} (d) $H_2PO_4^-$, HPO_4^{2-}

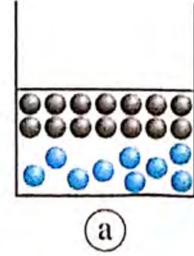
5 **In which of the following compounds the mass percentage of hydrogen is higher ? ....**

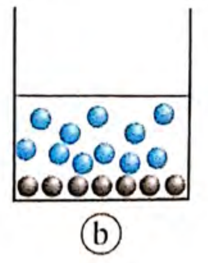
[H = 1 , Cl = 35.5 , O = 16 , S = 32]

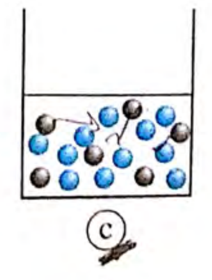
(a) HCl (b) H_2O (c) H_2SO_4 (d) H_2S

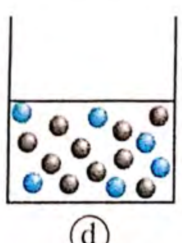
6 **Which of the following diagrams expresses the solution produced from dissolving sugar in water ? ....**




(a)


(b)


(c)


(d)

7 **Which of the following statements is correct ?** ....

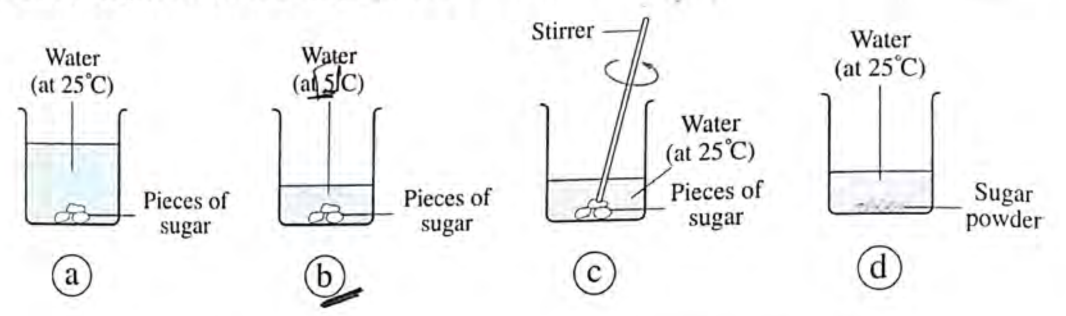
ⓐ The aqueous solution of magnesium oxide its pH value is less than 7

ⓑ The aqueous solution of sulphur trioxide its pH value is greater than 7

ⓒ Calcium oxide reacts with nitric acid forming salt and water.

ⓓ Carbon dioxide reacts with hydrochloric acid forming salt and water.

8 **In the experiment illustrated by the following figures, 2 g of sugar are used with different volumes of water at different temperatures, what is the state in which the dissolution process of solute in the solvent takes longer time ?** ....



9 **According to the reaction :** $C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$

on adding 100 g of yeast to 1 mol of $C_6H_{12}O_6$, 32.3 g of C_2H_5OH are formed, what is the percentage of the actual yield of C_2H_5OH ? .... [C = 12 , H = 1 , O = 16]

ⓐ 35.1% ⓑ 17.5%

ⓒ 100% ⓓ 32.3%

10 **What is the ionic equation which represents the formation of calcium carbonate salt, which is insoluble in water from the reaction of $CaCl_2$, Na_2CO_3 solutions ?** ....

ⓐ $Ca^{2+}_{(aq)} + CO^{2-}_{3(aq)} \longrightarrow CaCO_{3(aq)}$

ⓑ $Na_2CO_{3(aq)} + CaCl_{2(aq)} \longrightarrow 2Na^+_{(aq)} + 2Cl^-_{(aq)} + CaCO_{3(s)}$

ⓒ $Ca^{2+}_{(aq)} + CO^{2-}_{3(aq)} \longrightarrow CaCO_{3(s)}$

ⓓ $Na_2CO_{3(aq)} + CaCl_{2(aq)} \longrightarrow 2NaCl_{(aq)} + Ca^{2+}_{(s)} + CO^{2-}_{3(s)}$

11 **What is the difference between** silver nano particles **and** silver particles which can be seen by the naked eye ?

The nano Particles are measured in nano Scale, while the Paricles seen by naked eyes measured in macro Scale

1 mark

12 Show by symbolic equations, which reacts with larger volume of hydrochloric acid.
1 mol of sodium carbonate or 1 mol of sodium bicarbonate ?

$Na_2CO_{3(s)} + 2HCl_{(aq)} \longrightarrow 2NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$
1mol 2mol

$NaHCO_{3(s)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

Na_2CO_3 reacts with larger volume of HCl, Bec. the volume of solution increases by increasing the number of moles.

2 marks

13 Calculate the molality of the solution produced from adding 0.25 mol of potassium bromide to 1.25 kg of water.

$m = \frac{\text{no. of moles}}{\text{mass of solvent (kg)}} = \frac{0.25}{1.25} = 0.2\ m$

1 mark

14 What does happen when each of the following is added to a heterogeneous mixture of water and benzene ? With explanation.

(1) Oil.

oil will dissolve in benzene not water as it is non polar compound that dissolves in non polar solvent

(2) Potassium hydroxide.

it will dissolves in water as it ionic compound dissolves in polar solvent.

1 mark

15 Calculate the mass of 37.8 L of methane gas (at STP). CH_4 [C = 12 , H = 1]

$m.m = (12+4) = 16$

$\frac{mass}{m.m} = \frac{V}{22.4} \Rightarrow mass = \frac{V \times m.m}{22.4} = \frac{37.8 \times 16}{22.4} = 27\ gm$

1 mark

16 **Calculate the mass** of phosphorus vapours [P = 31] that contains the same number of molecules which are found in 4.23 g of sulphur vapours [S = 32].

m.m Phosphurous vapour ⇒ P_4 = 4 X 31 = 124 gm/mol

m.m Sulphur vapour ⇒ S_8 = 8 X 32 = 256 gm/mol

no. of moles = $\frac{4.23}{256}$ = 0.0165 mol

no. of molecules = no. of molecules

no. of moles = no. moles

mass = no. of moles × m.m = 0.0165 × 124 = 2.04 gm (P)

2 marks

17 **The opposite graph represents** the relation between the vapour pressure of (pure water and an aqueous solution) and the temperature,

Write beside each term of the following the appropriate number that represents it (in the graph)

1 atm, Pressure (atm), Temperature (°C), ①, ②, ③, ④, ⑤, ⑥

(1)	3	*freezing point of solution*	2	*vapour pressure of solution*	6	*boiling point of solution*
(2)	4	*freezing point of pure water*	1	*vapour pressure of pure water*	5	*boiling point of pure water*

Which is greater :

the difference between the boiling points of pure water and the solution **or** the difference between the freezing points of pure water and the solution ?

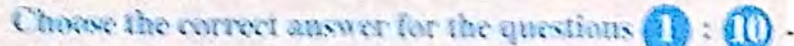
The difference between boiling points is great

2 marks

Booklet model 8

Rate your level

Superior	Remarkable	above average	Weak
from [illegible] marks to [illegible] marks	from [illegible] marks to [illegible] marks	from [illegible] marks to [illegible] marks	less than 10 marks


Choose the correct answer for the questions 1 : 10 . marks

1 **Which of the following prefixes do not represent its true value ?** ....

(a) Mega = 10^6 units. (b) Kilo = 1000 units.

(c) Deci = 10 units. (d) Nano = 10^{-9} of the unit.

2 **On mixing 2 mol of the substance (A) with 1 mol of the substance (B) according to the hypothetical equation : $3A + B \longrightarrow C + D$**

Then the limiting reactant will be .... , with explanation.

(a) A / Because its molar mass is the smallest.

(b) A / Because all its moles are consumed in producing the least number of products moles.

(c) B / Because the number of its moles is less than the number of moles of (A).

(d) B / Because 3 molecules of (A) react with 1 molecule of (B).

3 **A sample of oxygen gas its mass is 32 g contains ....** [H = 1 , O = 16]

(a) 6.02×10^{23} oxygen atoms.

(b) 1.204×10^{24} oxygen molecules.

(c) the same number of oxygen atoms found in 18 g of water.

(d) the same number of oxygen atoms found in 36 g of water.

4 **Why is glucose soluble in water, while benzene is not, inspite of both being organic compounds ?** ....

(a) due to difference of their molar masses.

(b) because glucose is an ionic compound, while benzene is a covalent compound.

(c) because glucose is a strong electrolyte, while benzene is a weak electrolyte.

(d) because glucose contains polar O – H bonds, while benzene contains C, H only.

5 **On measuring the boiling and freezing points of an aqueous solution of sodium chloride the readings of the two thermometers were** ....

(a) 98°C, –1.6°C (b) 100°C, 0°C (c) 102°C, –1.6°C (d) 102°C, 0°C

6. **On adding HX acid to water with stirring, there are two probabilities shown in the following figures :**

the first probability

the second probability

HX acid acts in ....

(a) the first probability as a weak acid and the second probability as a strong acid.

(b) the first probability as a strong acid and the second probability as a weak acid.

(c) the two probabilities as a weak acid.

(d) the two probabilites as a strong acid.

7. **One of the most famous sauces is prepared by whipping egg yolks, and during continuous whipping, oil is added drop by drop, then afterwards drops of vinegar are added, what is the classification of the mixture which composes this sauce ?** ....

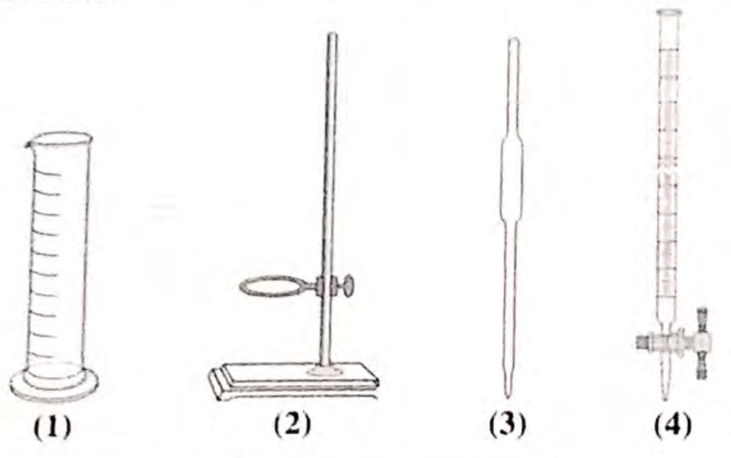
(a) Colloid (liquid in liquid).

(b) Colloid (liquid in solid).

(c) Suspension (solid in liquid).

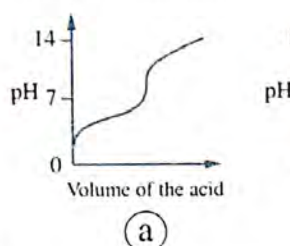
(d) Solution (gas in liquid).

8. **Which of the following tools would be used in a titration process ? and what is the missing tool ?** ....

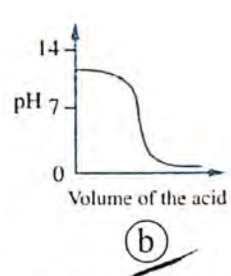


Choices	Used tool	Missing tool
(a)	(1) , (2)	Glass beaker
(b)	(2) , (3)	Analytical balance
(c)	(1) , (4)	Round - bottom flask
(d)	(2) , (4)	Conical flask

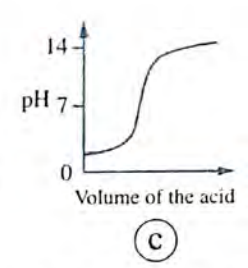
9 **Which of the following curves represents the titration of a weak base with a strong acid ?** ....



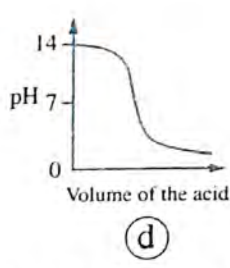
(a)



(b)



(c)



(d)

10 **Which of the following equations represents correctly the reaction of sodium carbonate solution with sulphuric acid ?** ....

(a) $Na_2CO_{3(s)} + H_2SO_{4(aq)} \longrightarrow Na_2SO_{4(s)} + H_2O_{(l)} + CO_{2(g)}$

(b) $CO^{2-}_{3(aq)} + 2H^+_{(aq)} \longrightarrow H_2O_{(l)} + CO_{2(g)}$

(c) $Na^+_{(s)} + CO^{2-}_{3(s)} + H_2SO_{4(aq)} \longrightarrow Na_2SO_{4(aq)} + H_2O_{(l)} + CO_{2(g)}$

(d) $CO^{2-}_{3(s)} + 2H^+_{(aq)} \longrightarrow H_2O_{(aq)} + CO_{2(g)}$

11 "Science fiction is becoming by time and efforts touchable facts"

Clarify the previous statement in the light of astronomers expectations regarding the use of carbon nano tubes.

Carbon nano tubes are very hard and very light, which may use in making spaceshuttles and elevators

1 mark

12 **Calculate the molality** of the solution produced from dissolving 2.7 g of CH_3OH in 25 g of H_2O [C = 12 , H = 1 , O = 16]

no. of moles = $\frac{mass}{molar\ mass}$ = $\frac{2.7}{32}$ = 0.0844 mole

molality = $\frac{no.\ moles}{mass\ of\ solvent\ kg}$ = $\frac{0.0844}{0.025}$ = 3.375 m

2 marks

13 Solid indium element reacts with chlorine to form $InCl_3$

What is the value of the coefficient of $InCl_3$ in the balanced chemical equation of the reaction ?

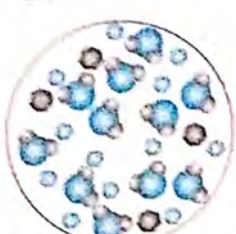
$2In + 3Cl_2 \longrightarrow 2InCl_3$

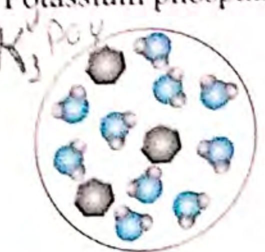
Coefficient = 2

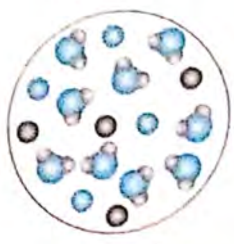
1 mark

14 The following figures represent the solutions of three different compounds which are :

- Sodium chloride.
- Potassium phosphate. K_3PO_4
- Glucose.

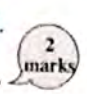






(1) Potassium phosphate (2) Glucose (3) Sodium Chloride

Write below each figure the chemical formula of the compound which represents it.

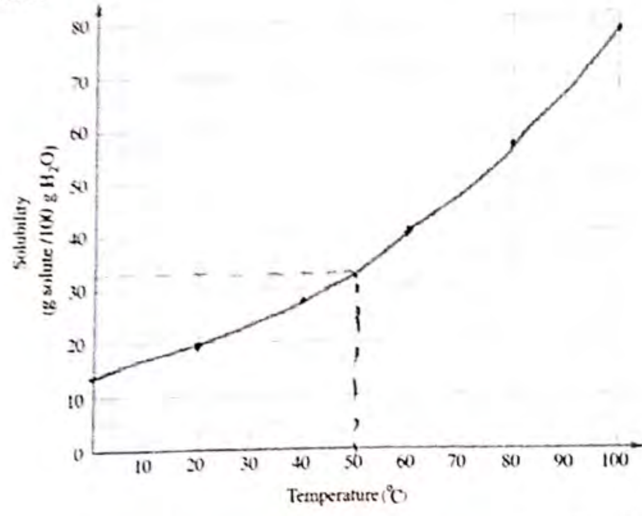


K_3PO_4 $C_6H_{12}O_6$ $NaCl$

15 The following table shows the masses of copper (II) sulphate required to be dissolved in 100 g of water to make several saturated solutions at different temperatures :

Temperature (°C)	0	20	40	60	80	100
Solubility (g solute/100 g H_2O)	14	20	28	40	56	77

(1) Use the values shown in the previous table to draw the solubility curve of copper (II) sulphate.



(2) What is the maximum mass of copper (II) sulphate can be dissolved in 100 g of water at 50°C ?

33 ≃ 34 gm

16 Complete the following equation : $H_2SO_{4(aq)} + H_2O_{(l)} \longrightarrow HSO_4^- + H_3O^+_{(aq)}$

and why water is classified in this process as a base ?

water is base as it accepts the H^+ Proton.

1 mark

17 4 balloons are inflated with four different gases at the same conditions of temperature and pressure, the mass of :

[H = 1] [He = 4] [Ne = 20] [O = 16]

- Hydrogen gas in the first balloon was 0.02 g
- Helium gas in the second balloon was 0.04 g
- Neon gas in the third balloon was 0.2 g
- Oxygen gas in the fourth balloon was 0.32 g

Arrange these balloons according to their volume, explain your answer with chemical calculations.

no. of moles = $\frac{mass}{molar\ mass}$

$H_2 = \frac{0.02}{1} = 0.01$ mole

He = $\frac{0.04}{4} = 0.01$ mole

Ne = $\frac{0.2}{20} = 0.01$ mole

Ballons are equals in volumes as they contains 0.01 mol and according Avogdros postulates they are equal of volumes as containg same no. of volumes.

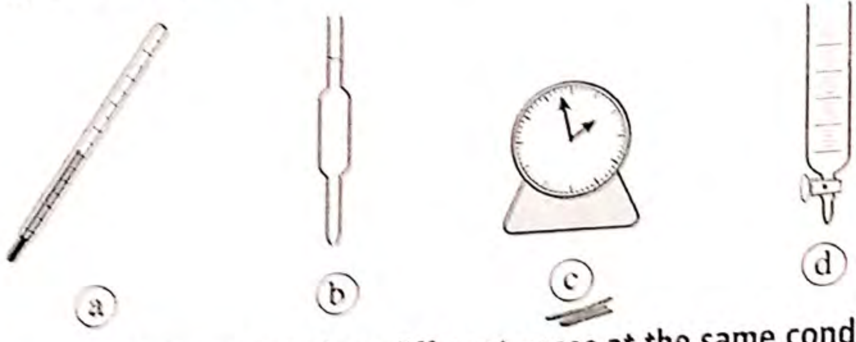
2 marks

Booklet model 9

10 marks

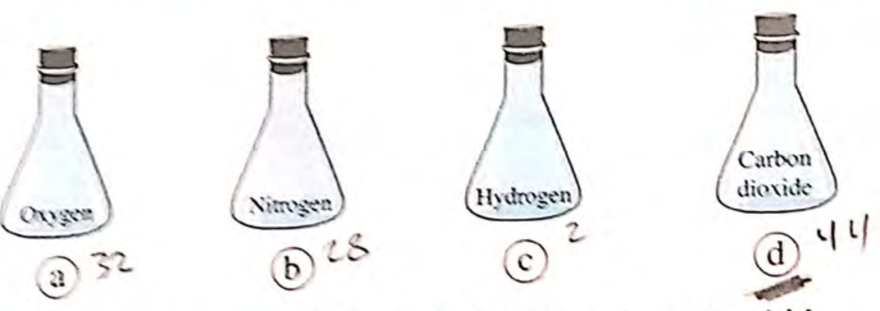
• Choose the correct answer for the questions 1 : 10 .

1 One of the students performed an experiment to measure the change in temperature on adding 25 mL of dilute hydrochloric acid to different volumes of sodium hydroxide solution. which of the following tools the student would not need during the performance of the experiment ? ....



2 In front of you 4 similar flasks contain four different gases at the same conditions of pressure and temperature. which of these flasks its molar mass is larger ? ....

[O = 16 , N = 14 , H = 1 , C = 12]



3 Which of the following ions can not behave as a base and as an acid in different reactions ? ....

ⓐ $H_2PO_4^-$ ⓑ CO_3^{2-} ⓒ HCO_3^- ⓓ HSO_4^-

4 What is the anion that exists in greater concentration in the solution which is produced from the reaction of 0.1 mol of H_3AsO_4 acid with 0.1 mol of sodium hydroxide ? ....

ⓐ $HAsO_4^{2-}$ ⓑ OH^- ⓒ $H_2AsO_4^-$ ⓓ Na^+

5 Sodium sulphate salt is found in many crystalline forms,
Which of the following sodium sulphate crystalline salts loses 43.2% of its mass on complete evaporation of all water present in it ? .... [Na = 23 , S = 32 , O = 16 , H = 1]

ⓐ $Na_2SO_4.H_2O$ ⓑ $Na_2SO_4.2H_2O$ ⓒ $Na_2SO_4.6H_2O$ ⓓ $Na_2SO_4.8H_2O$

6 A solution is prepared by dissolving 1.25 mol of an unknown substance in 1000 g of pure water, which of the following by measuring it we can conclude that the solute is an electrolyte or nonelectrolyte ? ....

(a) Temperature of water.
(b) Freezing point of solution.
(c) Volume of solution.
(d) Molar concentration of solution.

7 Which of the following ions produces gas bubbles on adding hydrochloric acid to its solid salt ? ....

(a) Cu^{2+}
(b) Fe^{3+}
(c) Al^{3+}
(d) CO_3^{2-}

8 The opposite graphical figure represents the effect of temperature on the activity of one of the human digestive enzymes, this represents the integration between chemistry and ....

(a) physics.
(b) biology.
(c) pharmacy.
(d) agriculture.

9 Which of the following represents an empirical formula and a molecular formula in the same time ? ....

(a) C_5H_{12}
(b) C_5H_{10}
(c) C_4H_8
(d) C_4H_{10}

10 Ethane gas reacts with oxygen according to the equation :

$$2C_2H_{6(g)} + 7O_{2(g)} \xrightarrow{\Delta} 4CO_{2(g)} + 6H_2O_{(v)}$$

2 mol → 4 mol
2×22.4 → 4×22.4
4 → ?
? = 8 L

What is the volume of CO_2 (at STP) which is produced when 4 L of ethane gas reacts with excess of oxygen ? ....

(a) 2 L
(b) 3 L
(c) 4 L
(d) 8 L

11 How can the reaction of a concentrated solution of NaOH with 1 M $(NH_4)_2SO_4$ solution be indicated ? Write the balanced symbolic equation including the physical states of reactants and products.

$(NH_4)_2SO_{4(aq)} + 2NaOH_{(aq)} \longrightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)} + 2NH_{3(g)}$

We can indicate this by the evolving of ammonia gas with pungent smell

2 marks

12 The opposite two figures show the molecular structure of diamond and carbon nano tubes :

(1) Which of them is preferred as a heat conductor, diamond or carbon nano tubes ?

Carbon nano tubes

(2) Which is harder, carbon nano tubes or steel ? and why ?

Carbon nano tubes,
Due to strong bonds between
molecules

Carbon nano tube

Diamond

1 mark

13 Chloroethene compound C_2H_3Cl reacts with oxygen according to the equation :

$$2C_2H_3Cl_{(g)} + 5O_{2(g)} \longrightarrow 4CO_{2(g)} + 2H_2O_{(v)} + 2HCl_{(g)}$$

Calculate the number of H_2O molecules produced from reaction of 10 mol of C_2H_3Cl with excess of oxygen gas.

$2C_2H_3Cl \rightarrow 2H_2O$
2 mole $\rightarrow$ 2 mole
10 mole $\rightarrow$ 10 mole
no. of moles of H_2O = 10 mole
no. of molecules = no. of moles × Av. no.
$10 \times 6.02 \times 10^{23}$
$= 6.02 \times 10^{24}$ molecules

2 marks

14 Calculate the mass of magnesium oxide that can be obtained by reacting a sample of magnesium its mass is 2.4 g with excess of oxygen. [Mg = 24 , O = 16]

$2MgO + O_2 \rightarrow 2MgO$
$2Mg \rightarrow 2MgO$
2 mole $\rightarrow$ 2 mole
$2 \times 24 \rightarrow 2(24+16)$
$2.4 \rightarrow x$
$x = \frac{80 \times 2.4}{48} = 4$ gm

1 mark

15 According to the reaction shown by the equation :

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

What is the limiting reactant on mixing 1.5 mol of O_2 with 2.5 mol of SO_2 ?

$2SO_2 \rightarrow 2SO_3$ | $O_2 + 2SO_3$

2mole → 2mole | 1mole → 2mole

2.5 mole → X | 1.5 mole → X

$X = \frac{2 \times 2.5}{2} = 2.5$ mole | $X = \frac{2 \times 1.5}{1} = 3$ mole

SO_2 amount consumed to produce less amount of SO_3 moles

SO_2 is limiting reactant.

2 marks

16 Plan a practical experiment to prepare 3 L of K_3PO_4 solution with 0.2 M concentration Given that the molar mass of K_3PO_4 compound equals 212 g/mol

no. moles = Molarity X Volume of solution = 0.2 X 3 = 0.6 mol

mass = no. of moles X molar mass = 0.6 X 212 = 127.2 gm

add 127.2 gm of K_3PO_4 to 1 L of water and stir till complete dissolution complete the solution by water till 3L.

2 marks

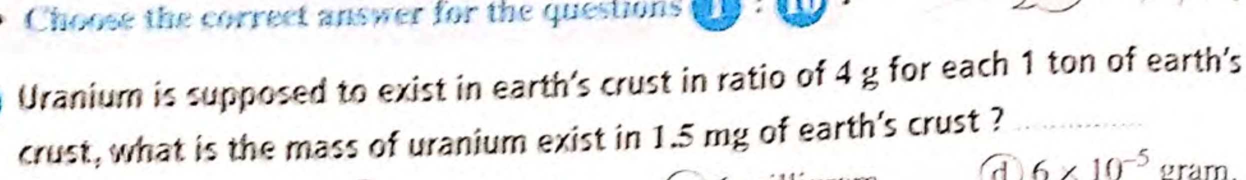
17 Calculate the depression in the freezing point of water, when an amount of nickel (II) nitrate salt is dissolved in it to form a solution, its molal concentration is 1 m, knowing that the molal freezing point depression constant of water is 1.86°C.kg/mol

Depression in freezing point = $\Delta t = K_f$ m solute

$= 1.86 \times 1 = 1.86$°C

1 mark

Booklet model 10



• Choose the correct answer for the questions 1 : 10 . (10 marks)

1. Uranium is supposed to exist in earth's crust in ratio of 4 g for each 1 ton of earth's crust, what is the mass of uranium exist in 1.5 mg of earth's crust ? ....

   (a) 6 nanogram. (b) 6 microgram. (c) 6 milligram. (d) 6×10^{-5} gram.

2. What does happen on mixing two equal volumes of 0.2 M K_2CO_3 solution with 0.2 M Na_3PO_4 solution ? ....

   (a) No precipitate is formed.
   (b) A precipitate of K_3PO_4 is formed.
   (c) A precipitate of Na_2CO_3 is formed.
   (d) A precipitate of K_3PO_4, Na_2CO_3 is formed.

3. The conjugate base of water is ....

   (a) O^{2-} (b) OH^- (c) H_3O^+ (d) H_2O_2

4. Which of the following choices is chemically correct ? ....

Choices	Strength of acid	Concentration of acid	pH
(a)	Strong	0.01 M	2
(b)	Weak	0.01 M	1
(c)	Strong	3 M	5.5
(d)	Weak	3 M	– 0.5

5. The following solutions are equal in concentration, Which of them is alkaline ? ....

   (a) LiCl (b) K_3PO_4 (c) $NaClO_4$ (d) NH_4NO_3

6. Phosphorus P_4 can be prepared from the following reaction :

$$2Ca_3(PO_4)_2 + 6SiO_2 + 10C \longrightarrow 6CaSiO_3 + 10CO + P_4$$

	$2Ca_3(PO_4)_2$	$6SiO_2$	$10C$
Molar mass	310 g/mol	60 g/mol	12 g/mol
Masses present in reaction medium	3370 g	1795 g	650 g

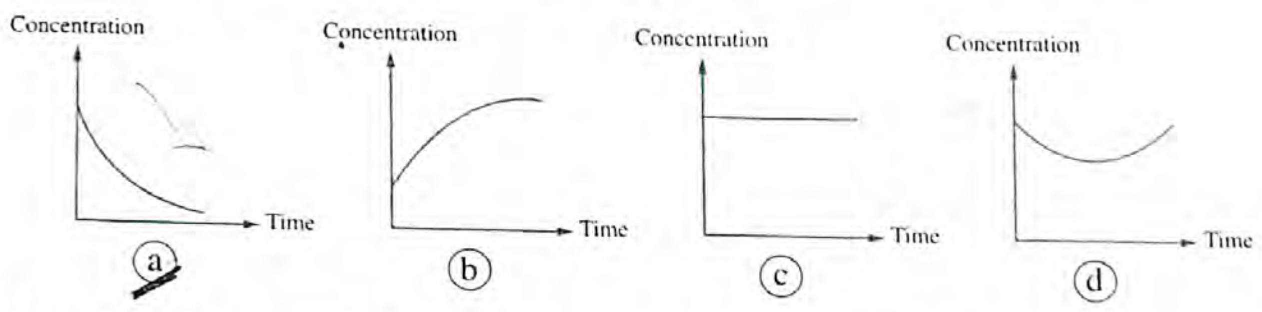
What is the limiting reactant for this reaction ? ....

   (a) C (b) $Ca_3(PO_4)_2$ (c) SiO_2 (d) P_4

7 **Which of the following values is not followed by a measuring unit ?** ....

(a) Molar mass.
(b) Nano shell diameter.
(c) Molal concentration.
(d) pH

8 **A mixture of ethanol (its boiling point is 78°C) and water (its boiling point is 100°C) can be separated by fractional distillation method, which of the following graphs expresses the concentration of the mixture by time ?** ....



9 **A sample of potassium chlorate $KClO_3$ was heated in an open test tube, so it decomposed according to the equation :**

$$2KClO_{3(s)} \xrightarrow{\Delta} 2KCl_{(s)} + 3O_{2(g)}$$

What is the percentage of the lost substance of potassium chlorate at the end of the reaction ? ....

[K = 39 , Cl = 35.5 , O = 16]

(a) 12%
(b) 28%
(c) 39%
(d) 30%

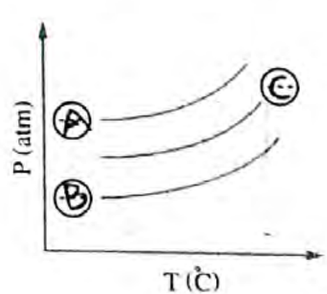
10 **The mixture of mud in water is** ....

(a) a heterogeneous colloidal mixture.
(b) a homogeneous suspension mixture.
(c) a solution whose contents can not be separated by filtration.
(d) a suspension mixture whose contents can be separated by filtration.

11 **The opposite graph represents** the vapour pressure curves for two pure liquids (A) and (B) and the solution resulted from mixing them (C).

If the liquid (A) is more volatile than the liquid (B),

Indicate each curve by one of the letters (A) , (B) or (C).



1 mark

12 The following three figures show the structure of graphene film which can be converted into single-walled carbon nano tubes and Bucky ball :

Graphene

Carbon nano tube

Bucky ball

(1) Compare between the rings forming each of graphene and Bucky ball

"in terms of : number of carbon atoms of each ring".

in graphene consists of 6 carbon atoms

bucky ball consists of 5 carbon atoms

(2) Mention another difference between carbon nano tube and Bucky ball **"other than the geometrical shape of carbon rings".**

nano tubes 2 dimensional

bucky ball is 3 dimensional

2 marks

13 The blood of adult person contains about 2.64×10^{13} red blood cells, the mass of iron in it is 2.9 g, Calculate the number of iron atoms in each red blood cell. [Fe = 55.85]

$2.64 \times 10^{13} \longrightarrow 2.9$

$1 \longrightarrow x$

$x = \frac{2.9}{2.64 \times 10^{13}} = 1.098 \times 10^{-10}$ gram

no. of moles in each cell $= \frac{1.098 \times 10^{-10}}{55.85} = 1.966 \times 10^{-12}$

no. of atoms = no. of moles × Avogadro no.

$= 1.966 \times 10^{-12} \times 6.02 \times 10^{23} = 1.18 \times 10^{12}$ atom

2 marks

14 **Calculate the molar mass of the compound produced from the combination of** potassium, and selenium which is located below oxygen in the modern periodic table.

[K = 39 , Se = 79]

K Se

1 2

K_2Se [2×39 + 79] = 157

1 mark

15 **Calculate the percentage of the practical yield,**

when 5 g of ethanol C_2H_5OH react with excess of potassium permanganate $KMnO_4$ to form 4.24 g of acetic acid CH_3COOH according to the equation :

$$3C_2H_5OH + 4KMnO_4 \longrightarrow 3CH_3COOH + 4MnO_2 + 4KOH + H_2O$$

[C = 12 , H = 1 , O = 16]

$3C_2H_5OH \rightarrow 3CH_3COOH$

3 mole → 3 mole

3(2×12 + 6 + 16) → 3×[(2×12) + 4 + 32]

138 → 180

5 → x

x = $\frac{5 \times 180}{138}$ = 6.52 gm.

% of actual yield = $\frac{actual}{theoritical}$ ×100 = $\frac{4.24}{6.52}$ ×100 = 65%

2 marks

16 **Write the chemical equations that represent the formation of the solution of each of the following substances :**

(1) $Na_2SO_{4(s)}$ (strong electrolyte).

$Na_2SO_4 \xrightarrow{H_2O} 2Na^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

(2) $CH_4N_2O_{(s)}$ (nonelectrolyte).

$CH_4N_2O_{(s)} \xrightarrow{H_2O} CH_4N_2O_{(aq)}$

(3) $HBrO_{(aq)}$ (weak electrolyte).

$HBrO_{(aq)} \overset{H_2O}{\rightleftharpoons} H^+_{(aq)} + BrO^-_{(aq)}$

1 mark

17 An unknown compound contains 24.2% carbon, 4% hydrogen and the rest is chlorine, **what is the molecular formula of this compound ?** given that molar mass is 150 g/mol

[C = 12 , H = 1 , Cl = 35.5]

assum mass 100 g

	Cl	C	H
mass	71.8	24.2	4
no. of moles	$\frac{71.8}{35.5}$	$\frac{24.2}{12}$	$\frac{4}{1}$
Ratio	2	2	4
	1	1	2

empirical CH_2Cl

Molar mass of empirical = (12 + 2 + 35.5) = 49.5

no. of units = $\frac{\text{molar mass}}{\text{empirical molar}}$ = $\frac{150}{49.5}$ = 3

molecular formula = $C_3H_6Cl_3$

2 marks